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**and**

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## *The Square Deal*

A further stage has now been reached in connection with the railway companies' proposals for changed conditions in respect to the conveyance of goods by rail by the publication of the Report of the Transport Advisory Council. Fundamentally, the trouble has arisen through the tacit assumption from a legal point of view that the railways enjoyed a monopoly in long distance transport of goods, but this position was changed very materially with the development of the motor lorry. If this Report of the Council be embodied in an Act of Parliament, as seems likely, since it was virtually unanimous, it should go far to eliminate much of the existing waste in the national transport system. The report stresses the need for the proper co-ordination of all forms of transport, and so far as the railway companies are concerned, it proposes to repeal the Acts governing the present system of rate-fixing, with its cumbersome methods of appeal to the Railway Rates Tribunal. The trader still has the right to refer to the Tribunal when a question of reasonableness is at issue. The second part of the machinery proposed in the Report, which comes first in point of time, is the provision for regular periodic meetings between the railways and the representatives of trade and industry for the purpose of discussing matters of common interest. Here it seems germane to remark that the appointment of a committee for the purpose of negotiating conditions with the railway companies should figure on the agenda for the next meeting of every employers' federation. No Report of this character would be adequate if it failed to take full cognisance of alternative means of transport, and as a result there now comes into being a "Road and Rail Central Conference." This body is drawing up voluntary agreements between the two parties. This does not mean that there will be an identity of charges between the two systems, but rather an alignment or correlation based on the nature of the services to be rendered. It is also sought to give a legal binding to the decisions arrived at, which decisions are to be subject to the approval of a tribunal. It is interesting to note that the rates charged by the canals are also to be changed to fall into line with the relaxations granted to the railways, and again the reasonableness of the charges is for the approval of the Railway Rates Tribunal. Coastwise shipping also has not been forgotten, and provision has been made for regular consultation between the two interests. Those who have followed the course of the negotiations consequent upon the railway companies' proposals must realise that much more has been accomplished than was originally intended. It is to be hoped that, as a result, the great transport industry, which is at the same time both the servant and customer of the foundry, will enjoy enhanced prosperity and be in a position better to satisfy the needs of the public.

## *The Swiss National Exhibition*

In 1920, we made an extensive tour of the metallurgical centres in Switzerland with the object of introducing an English type of electric furnace. We retain memories of a cordial and sympathetic reception, but no sales were made because, though the furnace was cheap in Swiss francs, its product was beyond the pockets of their foreign customers. To-day the problem is much the same, yet Switzerland, though small in area, possesses highly-developed and flourishing metallurgical and engineering industries. This is all the more remarkable since Switzerland must ever live by its exports, and actually about 85 per cent. of the Swiss production is sold in the world's markets. At the same time their standard of living and consequently their labour charges are high, and their supplies of raw materials are limited, so that most of them have to be imported. Consequently the Swiss products can only compete on quality—not on prices. Perhaps the plentiful supply of electricity in Switzerland, derived from their water power—their "white coal"—has been an important factor in the growth of quality production. At any rate, the engineering industry under these circumstances has developed, and in quality their products, which find their way all over the world, to-day rank high.

Naturally this state of affairs involves the production and use of high-quality castings of all types. This demand has been met in full by the Swiss foundries, and to-day names such as Fischer, Sulzer, Von Roll and Escher Wyss are esteemed throughout the foundry world when quality castings are under discussion. In the United States we learn that one make of steel castings is held in such esteem as to be thought to be made by some special, unique and highly secret process.

Now this summer—in fact, until the end of October—travellers on the Continent will have a unique opportunity of seeing something of Swiss enterprise for themselves at the Swiss National

Exhibition at Zurich. We have had the opportunity to visit many national and international exhibitions, but we feel that never have we seen so well planned and truly national a show as this. Its setting is, of course, ideal—on the shores of Lake Zurich, with the Alps as a "backcloth." The amusements are on one side of the lake and the serious exhibits on the other, the two parts being connected by a typical Swiss aerial cable railway.

For foundrymen the main interest lies in the Metals Pavilion, for here, as in the rest of the exhibition, the effort is co-operative and the names of the individual exhibitors are subservient to the general plan of exhibiting nationally rather than individually. The foundry exhibit, organised jointly by the Swiss Foundrymen's Association and the leading manufacturers, is outstanding, and is certainly the best planned and laid out we have yet seen. In the iron-foundry section the complete evolution of a casting is demonstrated down one side of the pavilion. First there is checking and testing of raw materials with a complete laboratory set-up especially for sand control. This leads to an exhibit of full-scale sand-preparing plant. Moulding machines and core-making machines follow, and here the birth and growth of a complex mould for a Diesel-engine frame are shown. A full-sized sectioned cupola with an exhibit of the pig-iron and cokes used leads to an exhibit of the engine frame as cast and finally fettled. Full-scale foundry equipment accompanies the exhibit throughout and demonstrates that Switzerland has not neglected this field. The ferrous foundry section is completed by a show of typical Swiss castings ranging from a few ounces to several tons in steel, malleable, grey and alloy cast irons. Of special interest are the castings for the leading Swiss industries—Diesel engines, machine tools, locomotives, water and steam turbines and pumps. An outstanding casting is a pump impeller weighing 20 tons and about 10 ft. in diameter.

The non-ferrous casting industry is equally well represented—especially the aluminium section—since Switzerland is an important producer of that metal. Adjoining pavilions give an interesting insight into Swiss engineering enterprise, —from the largest power generation installations down to watches and clocks, for which Switzerland is famous. The railway section is of special interest, and here one can walk through the largest locomotive in the world—an electric engine of 12,000 h.p. with some 28 wheels and nearly 100 ft. long.

Any of our readers travelling on the Continent this summer, for business or pleasure, will find much of interest and value in the Swiss National Exhibition, and are well advised to arrange their itinerary to include at least one day at Zurich.

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(*Continued from next column.*)

The writer is emphatic about these points as the result of hard-gained experience over a number of years. It is not sufficient to have the facing sand in good condition and possessing a good permeability unless the backing sand also possesses a satisfactory permeability.

I have always viewed permeability in association with pressure; perhaps this is hardly scientific, but it does work in practice. In practical terms it means, "release the pressure, however slight, from the surface of the mould as quickly as possible." The rate of this release depends upon a number of factors, such as the speed of pouring, gating, depth of facing sand, and most decidedly the relationship of the facing sand characteristics with those of the sand following.

It should be mentioned that these remarks apply more particularly to green-sand castings.—Yours, etc.,

H. H. SHEPHERD
(Chief Metallurgist, Crane, Limited).
Nacton Works, Ipswich.
May 24, 1939.

# Correspondence

*[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]*

### Modern Sand Testing

*To the Editor of* THE FOUNDRY TRADE JOURNAL.

SIR,—I would like to set down some impressions gathered as the result of reading Mr. Buchanan's excellent Paper on "Modern Sand Testing," and also the discussion which followed at the Sheffield Branch of the Institute of British Foundrymen.

In the first place I would like to say that, whilst one gets accustomed to reading the numerous contributions which Mr. Buchanan makes from time to time to scientific and general foundry technique, one looks forward with a great deal of interest to reading them, because, although we may not agree with all that he tells us, there is always something of value to be gleaned from the information which he puts forward.

If his recent Paper on sand testing resulted in nothing more than bringing to the fore a most interesting discussion on "scabbing" and facing sands, I am sure that Mr. Buchanan would agree that it well compensated him for the time he has spent in the work of his Paper. Of course, we do know that much general value will result to the industry from this recent work.

One impression that I gathered from reading the discussion was that there was some difference in opinion in defining "scabs," or at least the various types of scabs. I would therefore venture the suggestion that the Sands and Refractories Sub-Committee of the Institute might be asked to investigate this matter, and to arrive at some agreed definitions. For example—contrary to Mr. Buchanan—I am of the opinion that the buckle type of "scab," which I might suggest should be clearly defined as a "buckle-scab," generally arises from causes which are not altogether associated with the ordinary type of scab.

Incidentally I find that often on fairly large surface castings this type of "scab" can be eliminated by the addition of sawdust to the facing sand—a practice which Mr. F. Hudson reported on at length in THE FOUNDRY TRADE JOURNAL some two or three years ago.

Another impression gained was that quite a proportion of the discussion centred round the relationship of the properties of the backing sand to those of the facing sand. I think this brought forward a matter which is worthy of a great deal more attention by foundrymen. In the past too little attention has been given to this relationship. Perhaps it would be unfair to say that most foundrymen ignore this, but I do not think it would be far from the truth to say that many foundrymen do not appreciate the importance of balancing the backing-sand properties with those of the facing, and that in other cases the only attempt which is made to balance these two materials is by artificially venting from the back of the mould. The relationship becomes of vital importance if a casting is of such design that only a thin depth of facing sand is necessary.

During the discussion Mr. Pollard is reported to have made the statement:—"If they could not draw the steam away from just behind the facing sand, would poor backing sand have an influence?" My answer to this would be definitely "Yes."

Again:—"If a backing sand was in a bad condition (for instance, with a lot of silt in it), he thought it must have a detrimental effect on the surface of the castings." To this I would say "agreed," but the detrimental effect may not only be confined to merely the surface of the castings.

(*Continued in previous column.*)

# Notes from the Branches

*East Anglia.*—By kind permission of the directors of Booth & Brookes, Limited, a visit was made by the East Anglian Section of the Institute of British Foundrymen to the Mildmay Ironworks at Burnham-on-Crouch on May 18. About 40 members attended, including some from the London Branch.

The visitors learned that the firm was instituted at the beginning of the century by the father of the present directors, Sir Paul Booth and Mr. C. C. Booth. A variety of light iron castings are produced in the foundry, which at the present employs 150 men. Perhaps the most outstanding of the castings produced are pianoforte frames, in which the firm specialises. Frames bearing the names of all the well-known makers of pianos were seen in different stages of manufacture. Much interest was shown in the spraying process, whereby the frames receive a beautiful golden bronze finish.

Among other things the visitors saw in the making were cast-iron window sills and parts for both gas and electric cookers. Hot-plate castings for the latter are sprayed with molten aluminium, which makes them more heat resisting. Electro-plating plants for copper and nickel provided the finish on other small castings. Beautiful examples of the skill and art of the moulder were in evidence in the form of intricately designed ornamental open-work castings and plaques, with an antique bronze finish.

At the termination of the inspection the party was entertained to tea in the works canteen. COLONEL C. PORTWAY thanked the directors and guides, and was supported by MR. H. H. SHEPHERD. MR. C. C. BOOTH made a brief acknowledgment.

# Census of Production, 1935

The Final Report of the Fifth Census of Production and Import Duties Act Inquiry for the year 1935, Part II, has been issued. The preliminary results of the Census, which were issued in the course of the year 1937, were limited to summarised statements of the quantities and selling values of goods produced (with a comparative statement of exports and retained imports), the quantity and cost of materials, fuel and electricity used, and the numbers of persons employed. They provided all the information that was available on these matters at the time of publication, but the figures given were provisional and a number of amendments have been incorporated in the Final Report as a result of the receipt of further returns and the revision of some of the particulars originally tabulated. Apart from revision of the provisional figures, the Final Report also contains information on a number of subjects of economic importance (*e.g.*, the location of industries, size of firms, etc.) which could not be dealt with conveniently in the series of preliminary reports. Part II deals with the following trades: Iron and steel (blast furnaces); iron and steel (smelting and rolling); iron and steel foundries; tinplate; hardware, chain, nail, screw and miscellaneous forgings; wrought iron and steel tube; wire; tools and implements, and cutlery; also engineering, shipbuilding and vehicles trades. Extensive abstracts of the principal summarised statements issued in 1937 dealing with the iron and steel and engineering industries appeared in the JOURNAL as they were published. Copies of Part II of the Final Report may be obtained from H.M. Stationery Office, York House, Kingsway, London, W.C.2. (price 8s. net).

# The MnS-CaO System

A study of the MnS-CaO system at medium and high temperatures, conducted by D. MIREW and forming the subject of a report in the "Archiv für das Eisenhüttenwesen," indicates that appreciable desulphurisation of a molten steel with manganese can only be achieved in the absence of basic lime slags. If excess lime is also present, the latter will be mainly responsible for the desulphurising action.

# Hardening and Tempering Grey Cast Iron*

## SOME OF THE FACTORS INVOLVED

By G. A. TIMMONS, V. A. CROSBY and A. J. HERZIG

[ABSTRACT.]

The possibility of expanding the field of usefulness of a material, the basic advantages of which cannot be questioned, lies in the practice of heat-treating grey cast iron. The heat-treatment of grey cast iron has been practised in one form or another for many years. In this practice little attention has been given to the inherent difference between steel and cast iron. Its response to the various well-known treatments applied in the past has been of such practical importance that heat-treatment has now become a significant part of the metallurgy of cast iron.

The types of treatment most commonly practised fall into three classes: (1) Tempering to relieve internal stresses; (2) annealing to decrease hardness; and (3) rapid cooling from above the critical temperature to increase the hardness and strength, generally followed by a tempering treatment to modify the "as-quenched" characteristics. These three classes do not represent the only methods which have been used to change the properties of cast iron subsequent to solidification. Nitriding, and, more recently, induction hardening and flame hardening, have also been applied. With the exception of nitriding, these practices are in reality sub-headings of class 3.

Tempering grey cast iron to relieve internal stresses simply implies that the iron be raised to a temperature in the order of 425 to 850 deg. C. for a sufficient length of time to permit movement in the casting releasing the stresses. This practice has largely superseded the older ageing treatment which consisted in allowing the castings to remain in the foundry yard for a relatively long period of time. Stress-relief tempering merely shortens that time, and has little effect on the hardness and tensile strength of the iron. The practical advantage gained is the prevention of distortion after machining.

TABLE I.—*Compositions of Cast Irons Produced Commercially by the Duplexing Process.*

| | No. 1. | No. 2. |
|---|---|---|
| | Per cent. | Per cent. |
| T.C .. .. | 3.19 | 3.10 |
| C.C .. .. | 0.69 | 0.70 |
| Gr .. .. | 2.50 | 2.40 |
| Mn .. .. | 0.76 | 0.80 |
| Si .. .. | 1.70 | 2.05 |
| Mo .. .. | 0.013 | 0.45 |
| Cr .. .. | 0.03 | 0.27 |
| Ni .. .. | None | 0.37 |

Annealing grey cast iron to decrease hardness and facilitate machining employs higher temperatures than those used in stress-relieving treatments. Subjecting grey cast iron to temperatures ranging from 685 to 785 deg. C. results in appreciable softening. Annealing is invariably accompanied by some degree of graphitisation which is partly responsible for the lower resultant hardness.

Hardening and tempering cast iron has more recently become common practice. By hardening and tempering, the structure of the "as-cast" iron may be greatly modified, thereby effecting important changes in the physical properties of the material. The ever-widening use of hardening and tempering of cast iron has led to some widely accepted but unproved opinions, the more prominent of which are:—(*a*) Hardened and tempered cast iron is superior to "as-cast" iron in all respects; (*b*) by simple heat-treating cycles the impact properties, transverse strength and deflection of cast iron may be controlled at will. It is intended to discuss in this Paper some of the factors involved in the hardening and tempering operations and to present the physical properties of a few commercial grades of hardened and tempered cast irons. The discussion and data will indicate that the hardening and tempering of cast iron involve some considerations not yet generally known.

* Paper, slightly abridged, presented to the Cincinnati meeting of the American Foundrymen's Association. The authors are associated with the Climax Molybdenum Company.

### Review of Literature

The changes which take place in cast iron when the temperature is raised from room temperature through the critical temperature have been recognised in the work of others. Especially has it been recognised that graphitisation and resolution of graphite may play a significant part in the response of cast iron to heat-treatment. McElwee suggested that graphitisation could take place below the critical temperature and that a resolution of carbon above this temperature was possible. Walls and Hartwell showed that the minimum hardness for a cast iron resulted from quenching the iron after a soak at 785 deg. C. They also pointed out that bars air-quenched from 980 deg. C. gave higher strengths at lower Brinell hardnesses, and that the hardness increases and the graphitic carbon content decreases as the quenching temperature is raised.

In Hurst's Paper entitled "The Heat-Treatment of Cast Iron by Hardening and Tempering," further reference to graphitisation and resolution of graphite on heating to temperatures above the critical is made. Hurst noted "that the hardening effect in cast irons is not of necessity proportional to the amount of combined carbon present initially" and "it would appear from results of this nature that the hardening effect may be brought about in part by the solution of graphite." Eddy stated "hardening reduces the strength from 10 to 40 per cent., the original strength being restored by progressively higher tempering." Ballay concluded "the importance of combined carbon which is a function of the chemical composition and thermal history is difficult to determine and has never been clearly established."

### PART I.—GRAPHITISATION AND GRAPHITE RESOLUTION AT QUENCHING TEMPERATURES

The effect of increasing the quenching temperature on the combined carbon content was determined on two cast irons commercially produced by the duplexing process and of the compositions shown in Table I. Samples 1.2 in. dia. by 2 in. long were cut from standard A.S.T.M. arbitration bars. Samples were placed in a furnace already at the desired quenching temperature, held in the furnace for one hour, and then immediately quenched into oil. One-half of each sample was used for hardness determination and microscopic examination, the other half for combined carbon content determination. The results of these tests are given in Table II.

The "as-cast" structure of the plain iron consists principally of graphite and pearlite. After quenching from 650 to 685 deg. C. the structure was still pearlite and graphite. The structure showed no apparent change, although the combined carbon content had been reduced to 0.38 per cent. and the Brinell hardness had dropped considerably. At 703 deg. C. the pearlite had become partially spheroidised, the carbon migrating to the graphite flakes, leaving the centre of the former pearlite grains a ferritic area. At 732 deg. C. there is more ferrite present. At 760 deg. C. and 785 deg. C. there are still traces of pearlite adjacent to the graphite flakes, and the ferrite has started to recrystallise, so evidenced by the formation of distinct grain boundaries bordering polygonal grains.

The temperature of 826 deg. C. produces a distinctly different type of structure. This temperature is evidently in the range shown on the equilibrium diagram, where ferrite, austenite and graphite can co-exist (the alpha + gamma + Ca area in the 2 per cent. silicon diagram of "Alloys of Iron and Silicon").

TABLE II.—*Results of Tests on Quenched Samples of Cast Iron.*

| | Plain cast iron. | | Cr-Ni-Mo cast iron. | |
|---|---|---|---|---|
| | C.C. Per cent. | Brinell hardness. | C.C. Per cent. | Brinell hardness. |
| As cast .. | 0.69 | 217 | 0.70 | 255 |
| After quenching from— | | | | |
| 650 deg. C. | 0.54 | 207 | 0.65 | 250 |
| 685 ,, | 0.38 | 187 | 0.63 | 241 |
| 703 ,, | 0.09 | 170 | 0.59 | 229 |
| 732 ,, | 0.09 | 143 | 0.47 | 217 |
| 760 ,, | Nil | 137 | 0.45 | 197 |
| 785 ,, | 0.05 | 143 | 0.42 | 207 |
| 826 ,, | 0.47 | 269 | 0.60 | 444 |
| 843 ,, | 0.59 | 444 | 0.69 | 514 |
| 871 ,, | 0.67 | 477 | 0.76 | 601 |

The iron was almost completely graphitised as the temperature approached 785 deg. C. The structures observed in the flame-hardened specimens dealt with later reveal that the rate of graphitisation is extremely rapid and the indications are that the sample had more than sufficient time to become ferrite and graphite. Now as this area of alpha + gamma + Ca was reached, part of the ferrite absorbed 0.47 per cent. carbon, forming austenite grains which contained all of the combined carbon, leaving the remaining ferrite as it was before. During the quenching operation the austenite which had formed at 826 deg. C. transformed to fine pearlite.

The diagram in Greiner, Marsh and Stoughton's book, entitled "Alloys of Iron and Silicon," refers to a plane running through the solid, three-dimensional ternary diagram at 2 per cent. silicon. With regard to this alpha + gamma + Ca area, the following statement has been made: "The alpha + gamma + Ca area (the pearlite interval) . . . exhibits a temperature variation with carbon which has not been found experimentally, but this simply means that graphitisation in high-carbon alloys reduces the amount of combined carbon to the extent that observed transformations are not the transformations of alloys of any total-carbon content, but are the transformation of alloys of lower combined-carbon content."

The diagram also indicates that with 2 per cent. silicon the eutectoid carbon concentration of an iron-carbon-silicon alloy will be at 0.55 to 0.60 per cent. carbon and the eutectoid temperature will be about 785 deg. C. The diagram indicates that the gamma solid solution is capable of dissolving 1.4 per cent. carbon at 1,100 deg. C. These values are, of course, altered by the presence of other elements.

Above 843 deg. C. the iron is all in the gamma phase and the combined carbon content depends on the temperature. As the temperature increases the combined carbon increases, resulting in higher hardnesses. Quenching the iron from above the critical temperature produces a microstructure of martensite and graphite. The combined carbon at this temperature results from a carburisation of the matrix by diffusion of carbon from the graphite flakes and is limited only by the solubility of carbon in gamma iron at any specified temperature and the time required for equilibrium conditions to be attained.

The alloy iron exhibits a similar trend but due to the alloys retarding graphitisation to such an extent that it cannot become fully completed in the short space of 1 hr. the carbon content never goes below 0.42 per cent. The peculiar looking structure found in the plain iron after quenching from 826 deg. C. is found in the alloy iron after quenching from the same temperature, although there is considerably less ferrite.

The structures as found in connection with the combined-carbon content and Brinell hardness, as reported in the table, support the notion that at temperatures in the neighbourhood of 685 deg. C. graphitisation begins and proceeds to completion if sufficient time is allowed at a rate dependent upon composition. These conditions were fulfilled in the case of the plain cast iron on the 760 deg. C. quench. In the case of the Cr-Ni-Mo cast iron, although graphitisation was occurring, it was proceeding at such a slow rate at this same temperature that in 1 hr. the combined carbon content had been reduced only to 0.45 per cent. from 0.70 per cent. When the iron was heated to higher temperatures resolution of the graphite occurred in both irons, the structure of the matrix finally becoming fully martensitic upon liquid quenching. It appears the earlier opinion, that the hardening of cast iron by quenching is dependent to an important degree upon the amount of carbon which has been redissolved prior to the instant of quenching, is fully confirmed.

## PART II.—GRAPHITISATION DURING RAPID HEATING

If the resolution of graphite is an important factor in the hardening of grey cast iron by quenching, some knowledge of the time involved in the process of graphitisation and resolution of graphite during heating is essential to the understanding of the hardening mechanism. The time factor may be all important in such practices as flame-hardening which has become popular during the last four or five years. Flame-hardening involves the rapid heating of the surface to a temperature well above the critical range by either air or liquid quenching. It was decided to examine the flame-hardening of six irons to determine whether or not graphitisation and resolution of graphite still controlled the hardening mechanism. The entire cycle in this flame-hardening experiment covered an elapsed time of not more than 1 min. The compositions of the iron used in this test are given in Table III.

TABLE III.—*Composition of Irons Used in Flame-Hardening Tests.*

| | Plain iron. | Mo iron-A. | Mo iron-B. | Ni-Mo. | Cr-Mo. | Cr-Ni-Mo. |
|---|---|---|---|---|---|---|
| T.C .. | 3.19 | 3.22 | 3.20 | 3.22 | 3.21 | 3.36 |
| C.C .. | 0.69 | 0.65 | 0.58 | 0.53 | 0.60 | 0.61 |
| G.C .. | 2.50 | 2.57 | 2.62 | 2.69 | 2.61 | 2.75 |
| Mn .. | 0.76 | 0.75 | 0.64 | 0.66 | 0.67 | 0.74 |
| Si .. | 1.70 | 1.73 | 1.76 | 2.02 | 2.24 | 1.96 |
| P .. | 0.216 | 0.212 | 0.187 | 0.114 | 0.114 | 0.158 |
| S .. | 0.097 | 0.089 | 0.054 | 0.067 | 0.071 | 0.070 |
| Mo .. | 0.013 | 0.47 | 0.48 | 0.52 | 0.52 | 0.47 |
| Ni .. | None | None | Trace | 1.21 | 0.06 | 0.52 |
| Cr .. | 0.03 | 0.03 | 0.005 | 0.02 | 0.50 | 0.35 |

### Flame-Hardened Specimens

One specimen 1.125 in. diameter by 4 in. long of each analysis was flame-hardened. Each specimen had a machined surface, was properly centred, and set up in a lathe. A special head with four tips using a mixture of oxygen and acetylene made possible a flame-hardened surface 1½ in. wide.

The flame-hardening operation was conducted at a speed of rotation of 400 r.p.m. From the instant the flame was brought into contact with the specimen until it was shut off and the sample flooded with water the total elapsed time was 40 sec. The maximum surface temperature was 810 deg. C.

Rockwell hardness determinations were made on concentric circles at various depths below the surface of each specimen. The average of ten readings on each circle is given in Table IV.

The structures of these samples were examined under the microscope, and it was found that in the case of the plain iron a transition zone occurred wherein even with this most rapid heating and cooling operation graphitisation had taken place. Microstructures paralleling those obtained from the quenched samples dealt with in Part I were found in the transition zone on plain iron, but, as would be expected, the alloy irons having slower graphitisation rates did not show sub-surface layers of high ferrite content.

TABLE IV.—*Rockwell C Hardnesses at Indicated Depths Below the Surface of Each Flame-Hardened Sample.*

| | Plain iron. | Mo-A. | Mo-B. | Ni-Mo. | Cr-Mo. | Cr-Ni-Mo. |
|---|---|---|---|---|---|---|
| Surface .. | 45 | 55 | 56 | 52 | 53 | 52 |
| Below surface— | | | | | | |
| 1/16 in. | 49 | 55 | 55 | 51 | 53 | 52 |
| 1/8 in. | 47 | 54 | 54 | 50 | 52 | 52 |
| 3/16 in. | 40 | 54 | 54 | 44 | 32 to 49 | 54 |
| ¼ in... | 20 to 39 | 32 to 50 | 50 | 40 | 18 to 32 | 53 |
| 5/16 in. | 20 | 32 | 30 to 48 | 19 | 18 | 52 |
| ⅜ in. | 18 | 16 | 18 | 19 | 18 | 31 |
| 7/16 in. | 16 | 16 | 18 | 19 | 18 | 17 |
| Centre .. | 10 | 10 | 17 | 16 | 16 | 15 |

The centres of the flame-hardened specimens were, for the most part, coarse pearlite. The plain iron, the two Mo irons and the Ni-Mo iron had small amounts of ferrite adjacent to the graphite flakes. There was no indication that the centres of these samples were raised to above 535 deg. C. and it is quite likely that the maximum temperature in any case was below 260 deg. due to the rapidity with which the surfaces were heated.

In the plain iron, this structure gradually changes to a transition zone wherein the coarse lamellae of the pearlite are spheroidized and the quantity of ferrite is increased. This condition grows to a maximum until almost all the pearlite has disappeared. The microstructures at this point have the same appearance as that yielded by the 785 deg. C. quench. The next zone has appearance of the 826 deg. quench, that is pearlite, ferrite and graphite. This zone then gradually merges into one where a low carbon martensite has evidently been formed by the quenching treatment. Here the ferrite is diminished somewhat. As the structure farther from the centre is examined the quantity of low-carbon martensite gradually increases at the expense of the ferrite until the ferrite has completely disappeared. As the outer surface is approached the martensite becomes acicular, probably due to the increase in combined carbon.

The structure found in the molybdenum irons was the same as in the plain iron except that there was no zone of ferrite and graphite. As far as could be ascertained there was no increase in ferrite at any point. After the zone where the pearlite had become partly spheroidized, there was an area composed of the light etching, low-carbon martensite and nodular fine pearlite with some ferrite which undoubtedly was not affected. As the structure closer to the surface was examined the ferrite decreased and the fine pearlite decreased, the martensitic structure becoming more and more dominant until, at the surface, the structure was composed entirely of graphite and martensite, the latter becoming coarser and more acicular near the surface.

The nickel-molybdenum iron had the same structures as the molybdenum irons except that in some locations there were small amounts of an acicular type of structure indicating that there had been a slight initiation of austenite transformation at temperatures around 371 to 426 deg. However, these starts of transformation had been arrested almost as soon as they started by the rapid quenching treatment which forced the rest of the austenite to transform at temperatures below 149 deg. C.

The chromium-molybdenum iron had no ferrite at all at the centre or at any other zone in the cross section. Evidently the chromium so stabilised the eutectoid carbide that none of it was able to dissociate in the short time required for heating. This iron contained a zone of transition composed of nodular fine pearlite and low-carbon martensite. The chromium-nickel-molybdenum iron had the same structures as the other alloy irons, the only difference being the depth of the hardened zone.

It is seen that graphitisation of plain grey cast iron is exceedingly rapid and that relatively small additions of alloys have a marked effect in reducing the graphitisation rate. The importance of reaching uniform temperatures well above the critical in treating plain grey cast irons is indicated.

## PART III.—PHYSICAL PROPERTIES OF QUENCHED AND TEMPERED GREY CAST IRONS

With the foregoing assurance that the time involved in the usual heating and quenching cycle was decidedly longer than required to complete the graphite resolution cycle, a study of the physical property changes made possible by hardening and tempering grey cast iron was undertaken. The same irons which were used in the flame-hardening experiment were heat-treated in the following manner.

The full-length transverse bars of each heat were placed in a furnace at 856 deg. C., held there for 1 hr. and oil-quenched directly from the furnace. One bar of each analysis was then tested in the as-quenched condition. The remaining bars were tempered. One bar from each iron was tempered at 200, 400, 600, 800, 1,000, 1,200 and 1,300 deg. F. (93 to 703 deg. C.). The tempering was accomplished by placing the bar in the furnace at the specified temperature and holding it there for 1 hr., after which time it was removed from the furnace and cooled in still air.

The " as-quenched " and " quenched and tempered " transverse bars were broken by transverse loading on 18-in. centres, recording the breaking load and the maximum deflection before fracture. Charpy impact test-bars 1.125 in. dia. by 8 in. long were machined from the broken test-bars without further treatment. After these Charpy impact specimens had been broken in testing, the broken halves of bars having Brinell hardnesses of over 300 were drawn at 593 deg. C. to facilitate machining of tensile specimens.

The tensile bars, A.S.T.M. bars with gauge-length diameters of 0.700 in., were then quenched into oil after 1 hr. in a furnace at 856 deg. C. The " as-quenched " specimens were tested without further treatment, and the remaining samples were drawn at the temperatures designated above. Except for the transverse tests, all tests were run in duplicate.

### Notes on Testing

The conditions under which the tests were run are as follow:

*Transverse Tests*:—All standard A.S.T.M. arbitration test bars—Specification A124-29. Broken on 18-in. centres.

*" As-cast " Tensile Test-Bars*:—0.800 in. dia. Specification A124-29.

*Quenched and Tempered Tensile Test-Bars*:—Same as A124-29, except diameter at gauge length = 0.700 in.

Impact test:—(*a*) Charpy type specimen—simple beam. (*b*) Specimen 1.125 in. dia.—machined surface—8 in. long broken on 6-in. centres—unnotched. (*c*) Velocity of hammer at instant of striking specimen = 18.1 ft. per sec. (*d*) Distance between centre of percussion and centre of rotation = 2.625 ft. (*e*) Weight of pendulum = 23.57 lbs. (*f*) Temperature of tests = 70 to 74 deg. Fah. (*g*) Initial energy of blow = 120 ft.-lbs.

Impact and tensile figures are in every case the average of values obtained in two separate tests.

Photomicrographs were made of the typical structures of the irons in the "as-quenched" condition, after the heat-treatment producing the highest tensile strength, and after tempering at the highest temperatures, 703 deg. C.

In order to obtain a general conception of the effects of quenching temperatures on these irons, one bar of each analysis (except molybdenum iron A) was heat-treated and the Brinell hardness determined as in Part I (see Table V). Physical properties of the irons as cast and as treated are given in Table VI.

A study of Table VI will show that quenching has produced the following changes in the properties of the irons:—(*a*) The Brinell hardness was increased; (*b*) the tensile strength was reduced; (*c*) the transverse strength and deflection were reduced, and (*d*) the impact strength was reduced.

On drawing the quenched irons at successively higher temperatures, the following modification of properties resulted:—(*a*) The Brinell hardness gradually decreased. (*b*) The tensile strength increased to a maximum at 406 to 528 deg. C. temper. At higher tempers the tensile strength decreased from this maximum. (*c*) A recovery of transverse strength and deflection values is realised reaching but not materially exceeding the values "as cast." (*d*) A recovery of impact strength occurs, but this recovery does not bring about impact strengths as high as the original "as-cast" values.

Comparing the properties after the quench and temper treatment producing the maximum strength, with the original "as-cast" properties, the following are found:—(*a*) Higher hardness. (*b*) Higher tensile strength. (*c*) Substantially the same transverse strength. (*d*) Reduced deflection. (*e*) Reduced impact strength.

TABLE V.—*Brinell Hardness of Various Quenched Irons.*

| Quenching temperature. Deg. C. | Brinell hardness.* | | | | |
|---|---|---|---|---|---|
| | Plain iron. | Mo iron B. | Ni-Mo. | Cr-Mo. | Cr-Ni-Mo. |
| As cast .. | 217 | 223 | 241 | 235 | 235 |
| 650 .. | 207 | 218 | 205 | 217 | 220 |
| 685 .. | 187 | 207 | 188 | 222 | 215 |
| 703 .. | 170 | 168 | 161 | 210 | 199 |
| 732 .. | 143 | 163 | 149 | 198 | 182 |
| 760 .. | 137 | 143 | 307 | 190 | 270 |
| 785 .. | 159 | 311 | 355 | 208 | 370 |
| 826 .. | 269 | 477 | 469 | 487 | 477 |
| 843 .. | 444 | 486 | 486 | 520 | 480 |
| 871 .. | 477 | 529 | 460 | 512 | 465 |

* Hardness determinations are the average in each case of four readings taken in a circle half-way from centre to outside of 1.2-in. dia. bar.

Comparing the quenched and tempered irons of the same (or approximately the same) Brinell hardness as the "as cast" iron, the heat-treated irons will be found to possess:—(*a*) Higher strength; (*b*) slightly lower transverse strength; (*c*) lower deflection; (*d*) lower impact strength.

The response of all the irons to the quench and temper treatment was qualitatively the same.

Hardenability specimens were prepared from one transverse bar of each analysis. This specimen consists of a solid cylinder 1 in. in diameter by 2¾ in. long drilled and tapped at one end for a ⅜-in. screw. This specimen was placed in a furnace at 856 deg. C. and held there for 1 hr. At the end of this time the specimen was removed and quenched in a fixture so designed that only the bottom surface of the cylinder was sprayed with water. This produces a continuous series of cooling rates throughout the length of each specimen, from a rapid water quench at the bottom end to an air cool at the top. Since size, quenching temperature, temperature of quenching medium, etc., are all constants, for all specimens, the hardness for corresponding points on the six specimens will be a function of the analysis of the irons and will be a criterion of the respective abilities of the irons to harden at a given cooling rate. Those who wish to obtain a better knowledge of this production method of checking hardenability are referred to a Paper presented before the A.S.M. by Jominy and Boegehold.*

Two flat surfaces were ground longitudinally on each specimen diametrically opposite each other. The final surface was 0.015 in. below the original cylindrical surface of the specimen. Rockwell hardness readings were made every ⅛ in. along these surfaces. Values from each side were averaged and tabulated in Table VII.

TABLE VI.—*Physical Properties of the Irons As Cast and Quenched and Tempering.*

| | B.H.N. | Transverse. | Deflect. Ins. | M.S. Lbs. per sq. in. | Impact. Ft.-lbs. | C.C. Per cent. |
|---|---|---|---|---|---|---|
| *Plain Iron.* | | | | | | |
| As cast .. | 217 | 2,620 | 0.304 | 37,200 | 31 | 0.69 |
| Quenched .. | 514 | 1,320 | 0.121 | 25,000 | 20 | 0.71 |
| Tempered at deg. C.— | | | | | | |
| 93 .. | 514 | — | — | 26,900 | 22 | — |
| 204 .. | 461 | — | — | 41,100 | 26 | — |
| 308 .. | 437 | 2,335 | 0.209 | 48,600 | 29 | — |
| 406 .. | 352 | — | — | 53,600 | 31 | — |
| 528 .. | 285 | 2,705 | 0.243 | 51,500 | 29 | 0.67 |
| 650 .. | 217 | 2,510 | 0.230 | 42,900 | 29 | 0.63 |
| 703 .. | 187 | — | — | 37,100 | — | 0.62 |
| *Mo Iron A.* | | | | | | |
| As cast .. | 223 | 2,820 | 0.276 | 43,100 | 41 | 0.65 |
| Quenched .. | 534 | 1,540 | 0.138 | 25,900 | 23 | 0.77 |
| Tempered at deg. C.— | | | | | | |
| 93 .. | 534 | 1,540 | 0.133 | 28,300 | 22 | — |
| 204 .. | 495 | — | — | 44,600 | 32 | — |
| 308 .. | 461 | 2,620 | 0.216 | 56,300 | 37 | — |
| 406 .. | 388 | — | — | 54,200 | 31 | 0.75 |
| 528 .. | 321 | 2,860 | 0.239 | 61,900 | 35 | 0.76 |
| 650 .. | 238 | 2,800 | 0.248 | 51,500 | 34 | 0.72 |
| 703 .. | 217 | — | — | 47,100 | — | 0.78 |
| *Mo Iron B.* | | | | | | |
| As cast .. | 223 | 3,060 | 0.272 | 43,000 | 44 | 0.58 |
| Quenched .. | 555 | 1,700 | 0.123 | 28,900 | 18 | 0.75 |
| Tempered at deg. C.— | | | | | | |
| 93 .. | 555 | 1,680 | 0.130 | 32,500 | 22 | — |
| 204 .. | 514 | 2,310 | 0.170 | 47,600 | 32 | — |
| 308 .. | 477 | 2,680 | 0.196 | 57,000 | 32 | — |
| 406 .. | 401 | 2,860 | 0.204 | 60,800 | 31 | 0.77 |
| 528 .. | 336 | 3,080 | 0.225 | 62,400 | 34 | 0.73 |
| 650 .. | 255 | 2,820 | 0.210 | 56,100 | 31 | 0.70 |
| 703 .. | 210 | 2,930 | 0.230 | 46,900 | 40 | 0.65 |
| *Ni-Mo Iron.* | | | | | | |
| As cast .. | 241 | 3,000 | 0.301 | 47,000 | 45 | 0.53 |
| Quenched .. | 514 | 2,290 | 0.224 | 33,800 | 31 | 0.87 |
| Tempered at deg. C.— | | | | | | |
| 93 .. | 514 | 1,610 | 0.140 | 32,800 | 31 | 0.87 |
| 204 .. | 469 | 2,750 | 0.245 | 54,500 | 43 | 0.81 |
| 308 .. | 444 | — | — | 61,200 | 41 | 0.78 |
| 406 .. | 375 | 3,170 | 0.271 | 63,300 | 39 | 0.72 |
| 528 .. | 321 | 3,020 | 0.259 | 55,800 | 31 | 0.66 |
| 650 .. | 241 | 2,550 | 0.232 | 52,200 | 36 | 0.67 |
| 703 .. | 190 | 2,390 | 0.237 | 40,000 | 36 | 0.35 |
| *Cr-Mo Iron.* | | | | | | |
| As cast .. | 235 | 3,190 | 0.315 | 48,400 | 46 | 0.60 |
| Quenched .. | 555 | — | — | 33,600 | 29 | 0.89 |
| Tempered at deg. C.— | | | | | | |
| 93 .. | 534 | 2,160 | 0.205 | 32,500 | 27 | — |
| 204 .. | 505 | 3,040 | 0.258 | 56,000 | 33 | — |
| 308 .. | 477 | — | — | 59,800 | 34 | — |
| 406 .. | 415 | 2,710 | 0.222 | 59,600 | 32 | 0.86 |
| 528 .. | 352 | 3,260 | 0.266 | 66,900 | 37 | 0.87 |
| 650 .. | 269 | 2,860 | 0.236 | 58,300 | 42 | 0.84 |
| 703 .. | 238 | 2,890 | 0.251 | 52,400 | 41 | 0.82 |
| *Cr-Ni-Mo Iron.* | | | | | | |
| As cast .. | 235 | 3,000 | 0.265 | 45,200 | 54 | 0.61 |
| Quenched .. | 514 | 1,540 | 0.141 | 25,300 | 25 | 0·80 |
| Tempered at deg. C.— | | | | | | |
| 93 .. | 514 | — | — | 27,900 | 24 | — |
| 204 .. | 477 | 2,090 | 0.176 | 42,400 | 33 | — |
| 308 .. | 444 | 2,970 | 0.246 | 52,500 | 44 | — |
| 406 .. | 401 | 2,990 | 0.246 | 52,300 | 37 | 0.74 |
| 528 .. | 331 | 2,990 | 0.251 | 56,300 | 36 | 0.82 |
| 650 .. | 262 | — | — | 50,700 | 45 | 0.81 |
| 703 .. | 228 | 2,950 | 0.270 | 45,400 | 45 | 0.74 |

Points from three of the irons were plotted, producing the curves shown in Fig. 1. These results are interesting in so far as they show that the effect of alloys on the hardenability of cast iron parallels the effect in steel already widely accepted.

* Jominy, W. E., and Boegehold, A. L., "Hardenability Test for Carburising Steel," Trans. A.S.M., Vol. 26, pp. 574-599 (1938).

### Recapitulation

There are certain inherent differences between steel and cast iron which result in significant modifications in the response to the usual quenching and tempering operations. When a pearlitic steel is heat-treated by quenching and drawing, the process consists in raising the temperature of the steel above its critical temperature, in other words, to a temperature where all the carbon present is in solution in gamma iron, then cooling the steel sufficiently rapidly to cause this solid solution, austenite, to transform at temperatures in the range 150 deg. C. to room temperature. The product of this low-temperature transformation is acicular in nature and is called martensite. Subsequent tempering results in a precipitation of carbide particles. The size and distribution of these particles depends upon the time and temperature of the tempering operation, and the agglomeration of carbides is the only change in structure on tempering.

The same structural changes take place in the quenching and tempering of cast iron, but in addition there is always present in a grey iron an excess of carbon as graphite. An unalloyed pearlitic iron containing 2 per cent. silicon in the as-cast condition usually contains 0.60 to 0.65 per cent. combined carbon. This is somewhat higher than the concentrataion of the eutectoid, and is primarily due to the fact that equilibrium conditions cannot be attained during the cooling of the castings which takes place at a comparatively rapid rate. The alloyed irons show even higher combined carbon contents although there may be no carbide present as primary cementite. In this connection, it is interesting to note in Part I that the plain iron after tempering for 1 hr. at 685 deg. is still composed of pearlite and graphite although the combined carbon has been decreased by about one half.

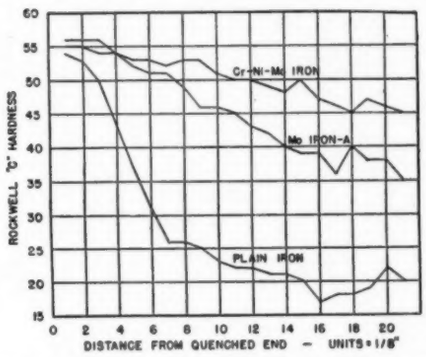


FIG. 1.—GRAPH OF HARDNESS IN HARDENABILITY TESTS.

TABLE VII.—*Hardenability Data—Quenching Temperature, 856 deg. C.*

| Distance from quenched end. | Rockwell hardness. | | | | | |
|---|---|---|---|---|---|---|
| | Plain iron. | Mo A. | Mo B. | Ni-Mo. | Cr-Mo. | Cr-Ni-Mo. |
| In. | | | | | | |
| ⅛ | 54 | 56 | 53 | 54 | 56 | 55 |
| ¼ | 53 | 56 | 52 | 54 | 55 | 55 |
| ⅜ | 50 | 56 | 52 | 53 | 56 | 54 |
| ½ | 43 | 54 | 51 | 53 | 55 | 54 |
| ⅝ | 37 | 52 | 50 | 52 | 55 | 53 |
| ¾ | 31 | 51 | 49 | 52 | 54 | 53 |
| ⅞ | 26 | 51 | 46 | 52 | 54 | 52 |
| 1 | 26 | 49 | 45 | 52 | 54 | 53 |
| 1⅛ | 25 | 46 | 45 | 52 | 53 | 52 |
| 1¼ | 23 | 46 | 44 | 51 | 50 | 51 |
| 1⅜ | 22 | 45 | 43 | 47 | 50 | 50 |
| 1½ | 22 | 43 | 44 | 47 | 49 | 50 |
| 1⅝ | 21 | 43 | 44 | 47 | 47 | 49 |
| 1¾ | 20 | 40 | 41 | 45 | 47 | 48 |
| 1⅞ | 19 | 39 | 40 | 45 | 44 | 50 |
| 2 | 17 | 39 | 40 | 45 | 41 | 47 |
| 2⅛ | 18 | 36 | 41 | 44 | 38 | 46 |
| 2¼ | 18 | 40 | 40 | 45 | 36 | 45 |
| 2⅜ | 19 | 38 | 37 | 45 | 34 | 46 |
| 2½ | 22 | 38 | 36 | 42 | 35 | 46 |
| 2⅝ | 20 | 35 | 35 | 42 | 32 | 45 |

(*Concluded on page* 441.)

# Some Jobbing Problems*

By F. G. JACKSON

### Hydraulic Cylinders and Rams

One of the first problems in hydraulic work is to decide how the cylinder or ram is to be cast—whether on the flat, banked or vertically. Many cylinders are cast on the flat or banked, but they are generally of small size. This enables them to be run sharply, and they can be cast without the employment of chaplets to hold down the core.

Large cylinders made on the flat or banked require the core to be held down in one or more places. This is not the only objection. A heavy hydraulic cylinder is a bulky casting which is never poured at white heat. Therefore, it must take a reasonably long time to pour. Metal climbing slowly up a wall between mould and core must not only be oxidising rapidly, but at the same time must be enclosing gases generated from the mould and core. The combination of these actions results in a seam of drossy metal along the top of the casting, which will probably

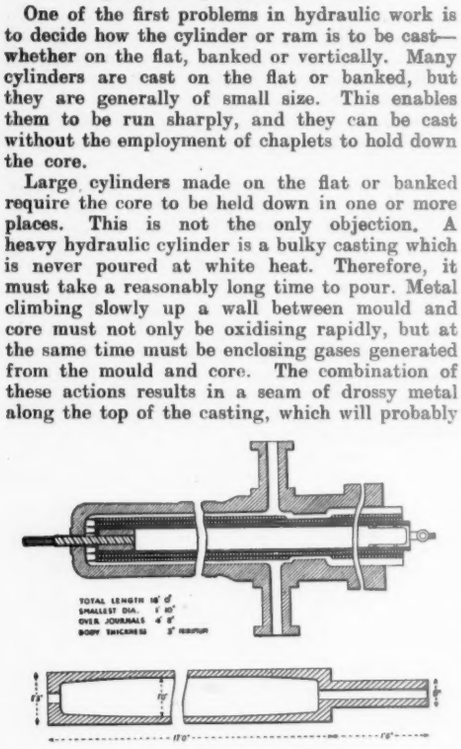

FIG. 1 (TOP).—HYDRAULIC CYLINDER OF GOOD DESIGN.
FIG. 2 (CENTRE).—LESS SATISFACTORY DESIGN.
FIG. 3 (BOTTOM).—POSITION OF RUNNERS AND RISERS.

sweat badly under pressure. A cylinder cast on a steep bank will not show these defects to the same extent.

Cylinders cast horizontally are known to have opened right along the top centre under water pressure. This sort of thing is unusual, of course, but there is no doubt that the method of casting leaves something to be desired.

Hydraulic cylinders and rams can be divided into two classes; types which can be machine-moulded and types which cannot. In the case of a cylinder with trunnions and several diameters, it would hardly pay to put a cylinder of this nature on a machine, even if boxes were available. The most economical way of moulding such work is horizontally, whilst the best way of casting it is vertically.

In the production of this class of work, there are seven main considerations:—

(1) A good loam sand is advisable on the bottom of the cylinder, for a distance of 3 to 4 in. up.

(2) A good quality loam, made up of sharp sand free from lime, and ball clay and manure, should be used. It should be crisp, hard and open. The straw rope should never be wound tight in one winding. The best method is to wind with a gap between the coils and tie up. Loam should be daubled on the rope and barrel and another rope pressed down between the coils of the first rope. This gives a bridging effect, causing each rope to be entirely covered by loam. Half an inch of loam should be applied and the core dried. The barrel should always be of largest possible diameter. A small core-bar with wind after wind of straw rope is not good practice. On the last coil a double ½ in. coating of loam is required.

On very long heavy cylinders, a few irons, 2½ ft. long, placed 3 in. apart at the bottom of the cylinder and wired in position, on the last layer of loam previous to the finishing coat, will be effective in preventing any swelling or distortion of the core. On this type of cylinder only ⅜ in. clearance is given between ram and cylinder wall. Any scab or swell has to be machined off. This means on a cylinder of this length, a very long boring bar, and it is both a costly and tedious job.

(3) Suitable design, meaning uniformity of section, without too many heavy pads and ribs, contributes to the production of good-quality work. Fig. 1 shows a cylinder of good design, illustrating the design of core bar and method of winding the core. Prints for the trunnion cores are in the main core to eliminate a feather edge on the inside. Fig. 2 shows a ram of awkward design. The section thickness is good, but the foundry has not been considered. Casting risks are increased by the very small holes allowed at each end. A better and completely safe job is to make the long narrow neck a separate casting, and screw and pin in position afterwards. This allows the full diameter of the core to come through the casting and suitable head metal can be added.

(4) The runners should always be nearer the mould than the core (Fig. 3), and the mould should be absolutely perpendicular, so that runners will not foul the core or mould. Incidentally, when considering runners, it is as well to err on the right side, keeping the runner choked off and releasing the chokes, if metal is on the dull side. Prints can always be juggled with to allow the runners to be filed out of the core prints. This is always the cheapest and cleanest method.

(5) Anchoring cores with the least amount of



FIG. 4.—METHOD OF ANCHORING CORE FIRMLY.

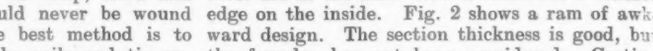

FIG. 5.—LOAM PATTERN OF HYDRAULIC CYLINDER WITH TRUNNIONS, BEING TRIED IN BOX. TRUNNIONS ARE HELD IN POSITION BY STRETCHER. NOTE DEPTH OF HEAD.

FIGS. 6 AND 7.—SCREW PUMPS IN AUSTENITIC CAST IRON, AS CAST. FIG. 8.—BATCH OF AUSTENITIC SCREW-PUMP CASTINGS. FIG. 9.—ANOTHER BATCH, SHOWING FEEDER HEADS.

* Extracts from a Paper read before the Wales and Monmouth Branch of the Institute of British Foundrymen. An earlier instalment was published in the Journal for March 9, 1939, pp. 212-4.

trouble and the maximum safety can be done by having a screwed journal and a lock nut above and below the bottom bar of the box. This is shown in Fig. 4.

(6) Many hints have been published as to how much head is required on hydraulic cylinders, but experience teaches far more than books, and it pays to be generous with heads. The practical man knows that they perform three main functions—cleaning, inducing pressure and lifting up the shrinkage patches. The author's notions are illustrated in Fig. 5.

(7) The author has always maintained that immense latitude is allowed with regard to metal. Many years ago foundrymen used to rely upon hematite. If a casting was in any way different or intricate, hematite was used. It has been a personal practice to eliminate hematites from pressure work, unless part of the charge was steel, when, of course, the hematite with its 4.0 per cent. carbon loses its identity, as hematite, and becomes low-carbon iron. Low-carbon iron with its close structure is ideal for pressure work.

For cylinders, a casting temperature of about 1,220 to 1,240 deg. C. and for rams from 1,250 to 1,280 deg. has been found to be suitable. Rams can be produced quite clean and free from gas holes at this temperature.

Sometimes lack of head room and crane facilities causes difficulty in upending cylinder and ram moulds and boxes. On a long cylinder, if four chains are used, and the bottom handles are slung at the top and the top handles at the bottom, the box will pick up at 45 deg. and can be laid on a bank in the pit and turned up quite easily. When turned up, the box should be well propped or it may topple during casting.

### Austenitic Cast Iron

Two or three years ago a little experience on small pump castings in austenitic irons conveyed to the author the many remarkable properties of nickel-alloy irons, but during the past six months his foundry has tackled this material in screw pump work (Figs. 6 and 7) in a bigger way. Eight screw pumps and sixteen steam-jacketed screw-pump bearing covers, along with glands and valve covers, were required in "Ni-Resist." Crucible melting was out of the question with such a job, which meant cupola melting with heavier oxidation losses and increased impurity pick-up. Personal experience, though short, led to the belief that trouble might be expected even with new metal, and further trouble when returns had to be used, especially when the intricate nature of the work was taken into consideration. Therefore, several precautions were taken, and on the first melt a pig with a carbon content of 3.5 per cent. was used. The castings shown in Fig. 8 were quite good.

On the second melt 25 per cent. returns were used, the balance being N.C.C. pig and "iron." This iron consisted of 50 per cent. 3.5 carbon material and 50 per cent. hematite with 4.0 per cent. carbon; the latter was used to raise the carbon. It must be realised that in the first place 20 per cent. of carbon-free metal is used and the carbon has to be around 3.00 per cent. to give good machinability. Carbon pick-up in the cupola was assisted by using extra coke on the charges. To keep oxidation losses low, a soft blast pressure of 5 ozs. associated with a tuyere ratio of 1 : 4 was used. Soda ash was used on each charge in addition to limestone, to keep the slag as lively and fluid as possible. This assists materially in keeping the sulphur low.

The metal when tapped was quite hot and undoubtedly superior to the crucible-melted product in this respect. The metal was poured instantly. The feeder heads, shown in Fig. 9, were set in the cope and the runner above the cope, so that the runner drains away into the mould and saves metal. When the metal had entered the feeder heads, pouring was stopped and the feeder heads filled up directly from the ladle.

The opinion, both as regards this particular metal and any other, has been formed that it does not pay, if it can be avoided, to have the runners at the bottom only. Bottom running means hot metal at the bottom and cooler metal at the top. The bottom of the casting must, therefore, be left to feed itself, as it will still be liquid while the top has frozen, and the feeder heads are useless. It is well known that this metal is non-magnetic, and thus all these castings were non-magnetic.

*(To be continued.)*

## Hardening and Tempering Grey Cast Iron

*(Concluded from page 439.)*

If a pearlitic iron is heated to a temperature of 856 deg. C. and held there for about three-quarters of an hour, the combined carbon is increased materially and may rise to as high as 0.89 per cent., as it does in the chromium-molybdenum iron. This increase in combined carbon results from solution and diffusion of the carbon from the graphite flakes present throughout the matrix. Thus, at the time of quenching, the cast iron part consists of a matrix of austenite of hyper-eutectoid carbon concentration and graphite flakes. When this is quenched in oil, the resulting structure is, in each case, an acicular martensite and graphite.

Upon tempering these quenched structures, the carbide trapped in the martensite, as a supersaturated solution of carbon in alpha iron, begins to precipitate and agglomerate as temperature and time are increased. The high silicon content of the iron-silicon solid solution, coupled with the already present inoculating nuclei of free carbon in the form of graphite flakes, tends to promote a migration of the carbon of the matrix toward these centres of graphitisation. This results in the possibility of lowering the combined carbon of the iron on tempering. As the tempering temperature increases, this diffusion progresses more rapidly until at temperatures of 760 to 785 deg. C., in relatively short time, the iron would become fully ferritic.

### Conclusions

(1) Graphitisation of unalloyed pearlitic cast iron takes place rapidly at temperatures from 703 to 785 deg. C.

(2) Resolution of graphite at temperatures above the critical takes place rapidly.

(3) The combined carbon content of the iron "as cast" has no effect on the carbon concentration in the austenite at the instant of quenching. The quenching temperature, the time at heat and the chemical composition, in order of decreasing efficacy, are the controlling factors.

(4) The effects of alloys on graphitisation rate and transformation rate are useful in controlling the hardenability of grey cast iron.

(5) The quenching and tempering of grey cast iron is an effective method for increasing the hardness and tensile strength. These improvements are obtained, however, at some sacrifice in shock resistance, transverse strength and deflection.

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FOLLOWING the resignation of Mr. Eric Shaw from the sales representation of the Austrian Magnesite Company, Limited, Mr. Alexander Samson, agent for the company, has taken over these additional duties.

Members of Birmingham Metallurgical Society, at their annual meeting last week, confirmed the election of Mr. A. Pinkerton as President. The election of other officers was approved as follows:—Vice-Presidents, Mr. C. H. H. Franklin, Dr. M. Cook, Mr. C. O. Wagner, Mr. D. Llewellyn; honorary treasurer, Mr. A. C. Craig; members of Council, Dr. T. A. Banfield, Mr. L. G. Hale, Mr. N. F. Fletcher and Mr. C. J. Smith.

## Higher Duty on Zinc

### PRICE STABILISATION PLAN

As from last Friday the import duty on unwrought zinc has been raised from 12s. 6d. to 30s. a ton. This decision, reached after long delay, is announced by the Treasury on the recommendation of the Import Duties Advisory Committee.

The increased duty is one of a number of proposals made by the committee for amending the arrangements introduced in 1935 following an earlier inquiry into the working of the lead and zinc agreements concluded at the Ottawa conference in 1932. The main proposals are as follow:—

Empire producers are to pay a sum of 10s. in cash to the Imperial Smelting Corporation, Limited, for each ton of zinc imported and sold by the Corporation in the United Kingdom; U.K. and Empire producers will co-operate in making a payment to U.K. consumers of zinc equivalent to 17s. 6d. per ton in respect of zinc contained in exported manufactured goods in which the cost of zinc is an important consideration; production of zinc metal by the Imperial Smelting Corporation is not to exceed 60,000 tons per annum; and the price of Empire electrolytic brands of zinc of a purity of 99.90 per cent., up to, but not including, 99.99 per cent. shall not exceed £3 per ton above the mean of London Metal Exchange spot and forward quotations.

The committee report that, after examining various suggested alternatives, the Empire producers put forward these proposals as the best practical method of dealing satisfactorily with the position. The Empire producers agreed that an effort should concurrently be made to reform the international cartel on a basis which would have for its object the stabilisation of the price between £14 and £16 per ton.

The consuming industries opposed the scheme on the grounds that they would be rendered more susceptible to competition both from foreign imports of zinc manufacturers and from alternative competing products, and that the export rebate arrangements would be difficult to administer.

## Patent Specifications Accepted

*The following list of Patent Specifications accepted has been taken from the "Official Journal (Patents)." Printed copies of the full Specifications are obtainable from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each. The numbers given are those under which the Specifications will be printed and abridged, and all subsequent proceedings will be taken.*

501,441. MYDDLETON, W. W. Treatment of the steel pipes and containers of chemical reaction chambers.

501,539. WALLACE, F. R. Sand or foundry moulding-machines.

501,634. TAIT, W. H. Apparatus for electrically testing the thickness of thin layers.

501,672. NAAMLOOZE VENNOOTSCHAP PHILIPS' GLOEILAMPENFABRIEKEN. Manufacture of alloys for permanent magnets.

501,698. NAAMLOOZE VENNOOTSCHAP MOLYBDENUM COMPANY. Electric heating-elements for high-temperature furnaces.

501,792. KRUPP GRUSONWERK AKT.-GES., F. Bearing for the rolls of rolling-mills.

501,808. DIXON, M. G. (Carnegie-Illinois Steel Corporation). Manufacture of rails.

501,889. MANNESMANNROHREN-WERKE. Production of tubes in pilger rolling mills.

501,892. BERGHAUS, B. Hardening, annealing, and the like of articles of metals or alloys.

501,905. STEWARTS AND LLOYDS, LIMITED. Process for the manufacture of metal tubes by push-bench apparatus.

501,953. NATIONAL MACHINERY COMPANY. Mechanism for shearing metal wire and like stock.

501,959. POWER FLEXIBLE TUBING COMPANY, LIMITED. Apparatus for the production of electrically-welded tubes from metal strip.

502,018. GRUNTHAL, M., and OMES (CONTINENTAL), LIMITED. Method of and means for manufacturing seamless hollow articles, such as projectile shells.

502,020. UHLENDORFF, O. Heat treatment of metals in molten salt baths.

502,196. BOHLER & COMPANY AKT.-GES., GEB. Manufacture of gear wheels from alloy steels.

# Castings for the British Gas Industry

By F. WHITEHOUSE

(*Continued from page 428.*)

### Metallurgical Problems

Discussion of the metallurgical problems of castings for gas production is hampered by the wide diversity of service conditions encountered, for in a single modern gas plant one could find instances of almost every type of cast iron, from the alloyed wholly-austenitic to the most common phosphoric grade; and even in a single retort regard is paid to localised conditions, except where "mutually antagonistic requirements necessitate a compromise."*

The castings illustrated come under different specifications, and even the same type of casting is manufactured to four or five different specifications, all of which have reference to local conditions encountered maybe in Cornwall and not in Scotland, or in Wales and not in Ireland. These conditions often concern the sulphur content of the coal as well as the type of water available locally, as, in the process of gas making, steam is introduced at certain points in the bottom ironwork, and the reactions are often complex and involved.

It follows that not only composition and physical properties, but also structure as affected by mould materials and cooling conditions must be under technical control in the foundry. Recent experience in the handling of what might be regarded as "sensitive" alloys, sensitive that is to mould conditions and temperature changes, indicates that test-bar results should be checked periodically where possible against the castings manufactured for sale, and particular regard paid to the conditions of test-bars and their manufacture if they are to serve as more than nominal indictations of the quality of material.

Tables III to V indicate results of a test of this kind. For the purpose of this test, six test-bars and three castings were poured from the same ladle of metal. Afterwards test-pieces and test-bars were taken from the castings themselves, in the manner shown in Fig. 27.

The test-bars were cast vertically and individually, and poured from the top. The castings were numbered 1, 2 and 3. No. 1 was cast in a dried mould and left in the sand 12 hrs., No. 2 in a green-sand mould and left in the sand 12 hrs., while No. 3 was cast in green sand and the top part lifted off 10 minutes after the casting was poured. A Brinell reading was taken on the sectioned pieces from the castings on the top face, the bottom face and the centre of the section. The section was ¾ in. The castings were poured in the order 1, 2, 3. The temperature at the cupola spout was approximately 1,400 deg. C., and the pouring temperature approximately 1,350 deg. C.

FIG. 27.—CASTINGS FROM WHICH TEST-BARS WERE TAKEN.

TABLE III.—*Brinell Hardness Tests.*

| Test-piece. In. | Edge. | | Centre of section. | |
|---|---|---|---|---|
| 0.875 (1) | 269 | | 228 | 5-mm. ball. |
| 0.875 (2) | 286 | | 228 | 750-kg. load. |
| 0.875 (3) | 332 | | 241 | 30 secs. |
| 1.2 (1) | 248 | | 217 | |
| 1.2 (2) | 248 | | 228 | |
| 1.2 (3) | 286 | | 248 | 10-mm. ball. |
| | Top. | Bottom. | | 3,000-kg.load. |
| Casting (1) | 218 | 220 | 200 | 30 secs. |
| Casting (2) | 232 | 232 | 207 | |
| Casting (3) | 253 | 251 | 221 | |

* J. G. Pearce. "Cast-Iron Research and the Gas Industry." The Institution of Gas Engineers. Publication No. 183/68.

Two sizes of test-bar were used, the British Standard 1.2-in. and the 0.875-in. types. Three of each made up the six and were marked 1, 2 and 3. The pair of bars marked 1, *i.e.*, one large and one small, were cast in dried moulds and left in sand 12 hrs. No. 2 pair were cast in a green mould and left in the sand 12 hrs. No. 3 pair were cast in a green-sand mould and taken out when they had reached a temperature of approximately 950 deg. C. and cooled rapidly by an air-blast. Test-bars marked 1, 2 and 3 were cut from the castings 1, 2 and 3. The physical test and the microstructures were from these test-pieces.

Transverse tests were taken in the "as-cast" condition, and the only cleaning treatment was to brush off adhering sand. Tensile tests were taken on one half of the broken transverse test-bar.

It will be seen from Tables III to V that neither size of test-bar gives a complete picture of the conditions of the casting, though the results in tensile strength on the 0.875-in. bar closely approximate the results obtained from bars taken from the castings themselves, and machined down to the same test-bar size. More particularly, it will be observed that differences in treatment are reflected alike in test-bar and in casting to roughly the same degree, though it cannot be said that the Brinell tests show any close relationship between casting and test-bar. No transverse tests were taken from the sectioned castings because it was felt that machined bars would be hardly likely to give a true reading, and it was not intended that future practice should cater for the machining of all transverse test-bars.

TABLE IV.—*Transverse Tests.*

| Test-piece. In. | Distance between supports. In. | Deflection. In. | Dia. at fracture. In. | Breaking load. Lbs. | Transverse rupture stress. Tons per sq. in. |
|---|---|---|---|---|---|
| 0.875 (1) | 12 | 0.14 | 0.845 | 1,437 | 29.5 |
| 0.875 (2) | 12 | 0.13 | 0.879 | 1,418 | 29.0 |
| 0.875 (3) | 12 | 0.12 | 0.868 | 1,358 | 27.7 |
| 1.2 (1) | 18 | 0.21 | 1.18 | 2,330 | 27.7 |
| 1.2 (2) | 18 | 0.20 | 1.13 | 2,283 | 27.0 |
| 1.2 (3) | 18 | 0.22 | 1.18 | 2,547 | 30.26 |

TABLE V.—*Tensile Tests.*

| Test-piece. In. | Diameter at fracture. In. | Load. Lbs. | Load. Lbs. per sq. inch. |
|---|---|---|---|
| 0.875 Bar (1) | 0.563 | 8,380 | 33,700 |
| 0.875 ,, (2) | 0.559 | 8,300 | 36,100 |
| 0.875 ,, (3) | 0.564 | 9,690 | 38,700 |
| 1.2 ,, (1) | 0.794 | 15,600 | 31,500 |
| 1.2 ,, (2) | 0.794 | 15,680 | 31,700 |
| 1.2 ,, (3) | 0.794 | 16,760 | 33,900 |
| Bar from casting (1) | 0.554 | 7,940 | 32,900 |
| ,, ,, ,, (2) | 0.552 | 8,850 | 37,100 |
| ,, ,, ,, (3) | 0.562 | 9,480 | 38,500 |

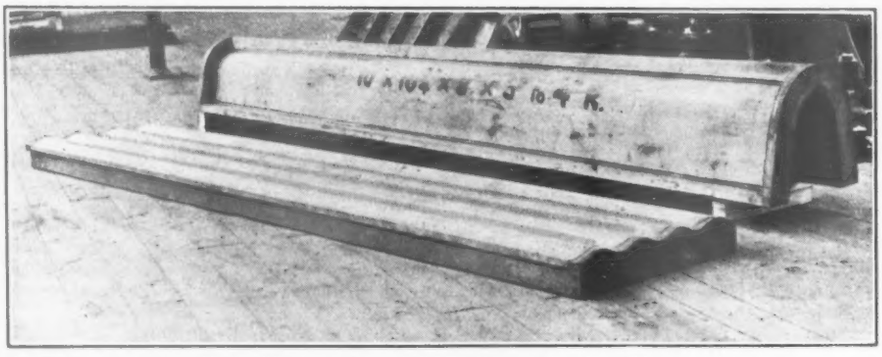
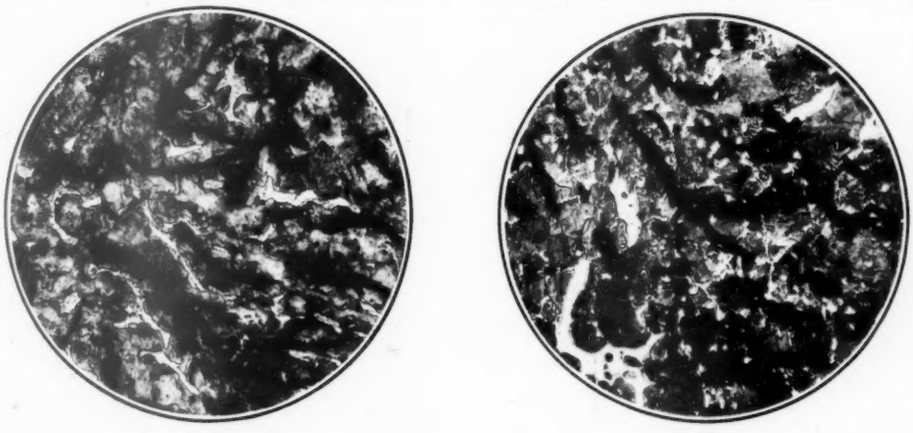


FIG. 28.—PATTERNS FOR A TYPE OF LOW-TEMPERATURE CARBONISATION RETORT, WHICH IS CAST IN SPECIAL HEAT-RESISTING IRON.

The real point at issue was to what extent test-bars could be held to give an adequate picture of the castings for sale, and in what degree changes in treatment could be reflected in test-bars, assuming the composition of the metal to remain constant.

The composition of the metal for the foregoing tests was:—T.C, 3.21; Si, 1.28; Mn, 0.89; S, 0.074, and P 0.32 per cent. Similar experiments are in hand on other types of metal, and an investigation is also being made into the effect of moderate temperatures on the modifications of structure induced by mould materials and foundry conditions.

It is not considered that chemical analysis and control of melting have little significance, but rather that mould materials and mould conditions, particularly in green-sand practice with sensitive irons, are factors to which scarcely enough attention has been paid. This applies with particular force where, as in the manufacture of gas plant, not only engineering properties must be obtained, but also a degree of heat resistance and corrosion resistance which strength figures do nothing to indicate. The microstructures referred to form an interesting commentary on this problem.



A. B.

FIG. 29.—SPECIMENS FROM THE RETORTS OF THE TYPE SHOWN IN FIG. 28. A, BEFORE GOING INTO SERVICE; B, AFTER 2½ YEARS' SERVICE. × 100.

### Low-Temperature Carbonisation

A sphere in which cast iron seems to be taking its place as a retort material is that of low-temperature carbonisation, of which in England there are many examples. Fig. 28 illustrates a type of casting used for building these retorts. They do, of course, operate vertically. In the instance given an oval section retort can be formed by bolting together the separate sections.

The operating conditions are that heat is applied on the outside and serves to coke the coal on the inside. The operating temperature for this process is approximately 650 to 700 deg. C., and it is imperative that the plates which form the retort should not only have long life but should neither distort nor crack. Given these properties, cast iron for low-temperature carbonisation has definite advantages over all other available materials at competitive prices. It is a field in which much can yet be accomplished.

Production in this case is from dried moulds, and, given selected raw materials and controlled melting, the foundry control rather follows the chilled-roll foundry practice, inasmuch as no casting is poured until a satisfactory chill test has been obtained. Distortion in the foundry is dealt with by special handling, and a stress-relief treatment at 650 deg. C. is also necessary previous to machining and to ensure satisfactory

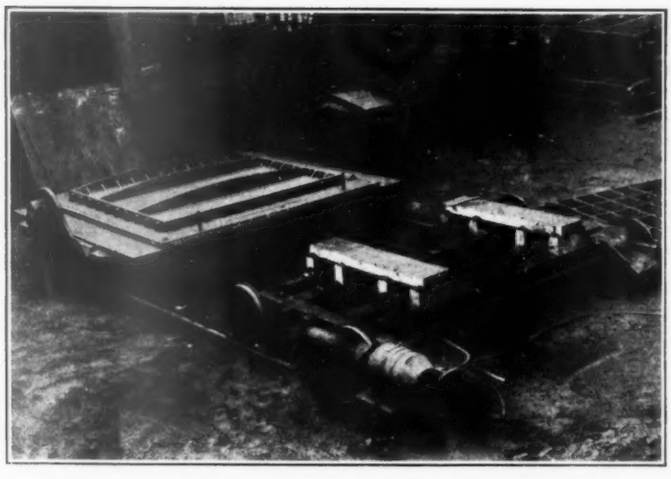


FIG. 30.—JOLT-RAM ROLL-OVER MACHINE FOR RAMMING DRAG PART FOR PURIFIER BOX SECTIONS.

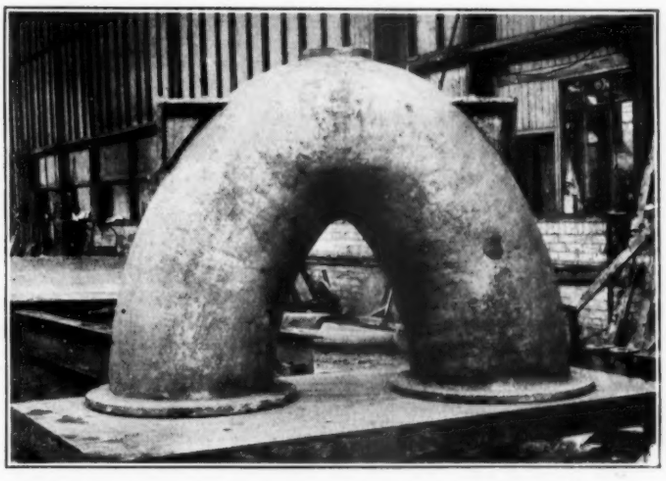


FIG. 32.—HYDRAULIC VALVE FOR GAS PURIFIER BOXES, 24 IN. DIA. AND 2,800 LBS. WEIGHT, MADE IN GREEN SAND.

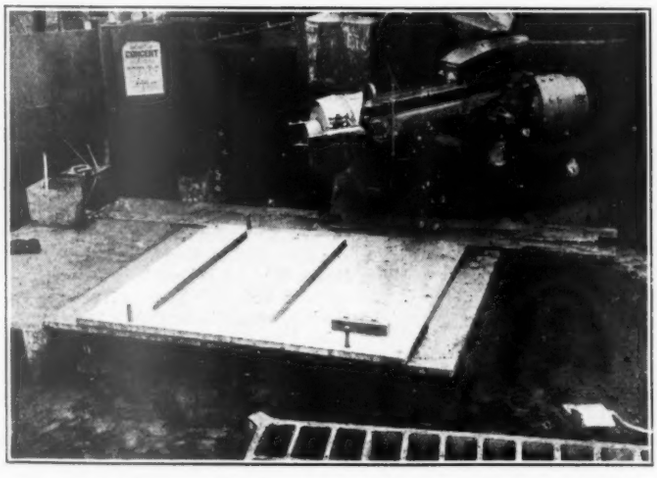


FIG. 31.—STATIONARY SANDSLINGER INSTALLATION FOR RAMMING COPE SIDE OF MOULD FOR PURIFIER BOX SECTIONS.

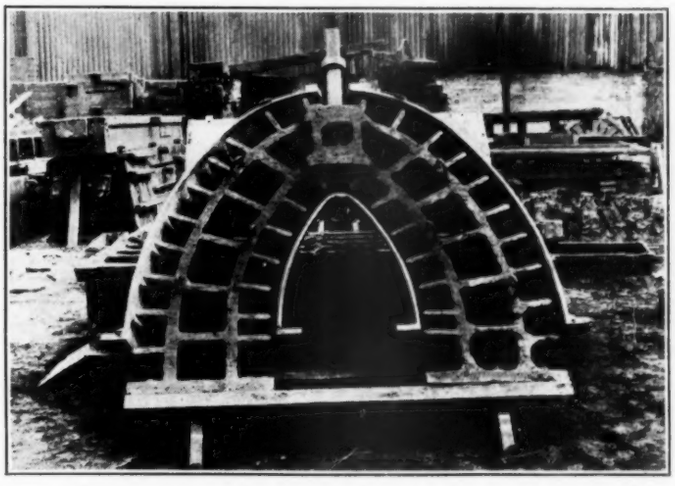


FIG. 33.—CAST-IRON SHELL PATTERN AND FABRICATED CORE IRON FOR MAKING HYDRAULIC VALVE.

working service. Figs. 29A and 29B show two stages in the life of these castings. The analysis of the castings is approximately:—T.C, 3.17; Si, 1.1; Mn, 0.72; S, 0.089; P, 0.10; and Cr, 0.5 per cent., and the tensile test on a bar taken from the casting previous to machining was 16 tons per sq. in.

There are, of course, castings in other systems of low-temperature carbonisation not illustrated here, and the problem there, as here, is not only one of composition but design and operating as well as manufacturing conditions.

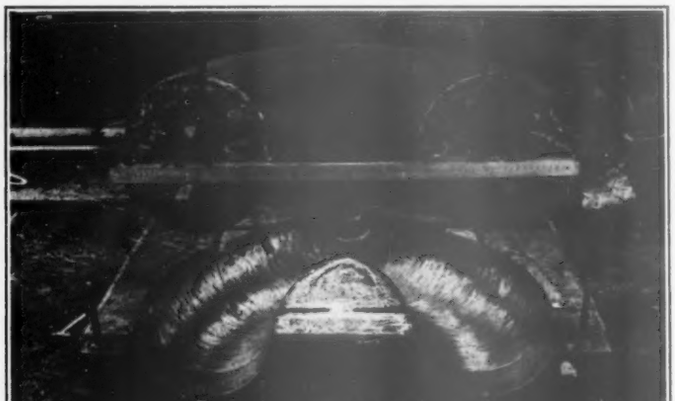


FIG. 34.—MOULD AND GREEN-SAND CORE FOR HYDRAULIC VALVE, READY FOR CLOSING.

### Gas Purification

Gas purifier boxes are still a job for the foundry in England, and the special corrosion-resisting properties of cast iron, together with the improved physical properties now obtainable, ensure a continuance of demand for at least some years to come. Figs. 30 and 31 show the foundry layout at the ramming end for the production of purifier box sections.

The plates forming the bottom of these boxes, which are 40 ft. by 40 ft., are 5 ft. square, and

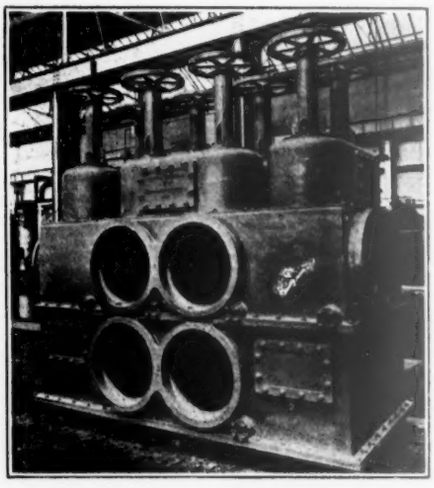


FIG. 35.—WECK VALVE IN CAST IRON, FOR REGULATION OF ENTRANCE AND EXIT OF GAS IN PURIFIER BOXES.

the side plates are 6 ft. 6 in. by 5 ft. Production is completely mechanised and the sand used is that of which particulars have been given earlier. All moulds are cast in green sand.

Fig. 32 shows a hydraulic valve for a gas purifier box. This again is an illustration of the use of a green-sand core and a fabricated core-iron. Figs. 33 and 34 will make the equipment provision for this kind of production quite clear. The diameter of the valve is 24 in. and the weight approximately 2,800 lbs.

Fig. 35 is a Weck valve used on some gas plant installations to control the entrance and exit of gas to and from the purifier box. Fig. 36 is a special type of gas-heater fixed in the pipe-line to the purifier boxes and used to control the temperatures of gas for its more rapid purification. The needle heater elements which form the medium for heat transference are also of cast iron and have needles in the bore of the pipe, as well as those which are obvious on the outside. These castings are made on a jolt-strip machine, and, so far as the mould itself is concerned, are cast green-sand. The inside is formed by oil-sand cores. All castings for gas purification are cast in a metal giving a

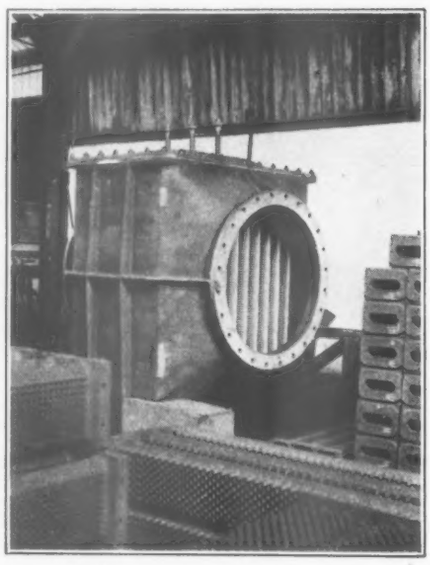


FIG. 36.—SPECIAL TYPE OF GAS-HEATER.

tensile test on a 1.2-in. bar of 15 to 16 tons per sq. in.

No attempt can be made to cover the field of by-product plant in the space available, but Fig. 37 illustrates typical individual sections from a still used in the production of ammonia from gas liquor. Again, different sizes and different designs are made. The foundry making plant of this kind must ensure soundness, less weight and higher tensile figures.

### Conclusion

It will be realised that this survey of castings for the British gas industry does little more than touch on the fringe of the matter. Much could be said about the intermittent vertical retort, the modern horizontal retort and types

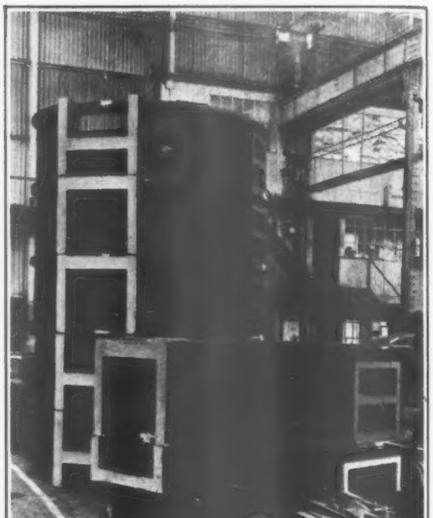


FIG. 37.—SECTIONS OF STILL FOR CONCENTRATION OF AMMONIA FROM GAS LIQUOR.

of continuous vertical retorts other than that used for illustration.

Finally, thanks are due to the Woodall-Duckham Company, of London, and to Newton, Chambers & Company, Sheffield, for permission to publish this Paper, and to Mr. R. C. Tucker, M.A., chief metallurgist of Newton, Chambers, for his personal interest and help.

## Testing of Materials

The Joint Committee on Materials and their Testing have now published the discussions on non-destructive testing held under their auspices in London on November 25, 1938. All the Papers then presented, with the report of the discussion and communications, are now available as reprints from the Journal of the Institution of Electrical Engineers.

The titles of the Papers included in the reprints are as follow:—

(1) "The Non-destructive Testing of Materials by Electrical and Magnetic Methods" by A. P. M. Fleming, C.B.E., D.Eng., M.Sc., and B. G. Churcher. (2) "Non-destructive Testing, based on Magnetic and Electrical Principles" by Dr. R. Berthold (Germany). (3) "Radiography—an Aspect of Non-destructive Testing" by V. E. Pullin, C.B.E. (4) "Industrial Radiography on the Continent of Europe" by Ir. J. E. de Graaf (Holland). (5) "Acoustic and General Methods of Non-destructive Testing" by S. F. Dorey, D.Sc. (6) "Modulus of Elasticity and Damping in relation to the State of the Material" by F. Förster, Dr. Phil, and Prof. W. Köster, Dr. Phil (Germany). (7) "Non-destructive Testing in the U.S.A." by H. H. Lester, R. L. Sanford, and N. L. Mochel.

Copies (about 81 pp.) are available in paper covers at the price of 3s. 6d. post free from the Secretary, the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

# Investigation and Modern Ideas on Enamel Control*

By G. H. ABBOTT, B.A. (Oxon), A.I.C.

*"Il y a vingt et cinq ans passez qu'il ne me fut monstré une coupe de terre, tournée et esmaillée d'une telle beauté que . . . dèslors, sans avoir esgard que je n'avois nulle connoissance des terres argileuses, je me mis à chercher les emaux, comme un homme qui taste on ténèbres."*—BERNARD PALISSY.

In these words Bernard Palissy describes how he was set on the track of enamels. As a boy he was taught the art of glass-painting, but the precariousness of the trade induced him when he grew up to turn his attention to the enamelling of earthenware. He had wholly to teach himself, and his first attempts were discouraged by repeated failure. He worked by the method of trial and error, pounding together all the substances likely to produce an enamel, and trying them out for himself in home-made kilns. He made hundreds of experiments, dissipating

(*Courtesy of British Museum Trustees.*)

FIG. 1.—BERNARD PALISSY.

his energy and means of livelihood before arriving at any result. After much hardship one of his mixtures turned out successfully, but he had been obliged to burn even his household furniture to reach the temperature necessary to melt it.

Dr. Samuel Smiles in his book "Self-Help" writes: "Palissy had already spent about ten years in search for the enamel, but it cost him nearly eight more years of experimental plodding before he perfected his invention. He gradually learned dexterity and certainty of result by experience, gathering practical knowledge out of many failures. Every mishap was a fresh lesson to him, teaching him something new about the nature of enamels, the qualities of materials, and the construction and management of furnaces."

When Palissy died in 1589 he had achieved an outstanding reputation as a potter, and his method of experiment by trial and error has lasted down to modern times. The special interest of his life to enamellers is that he rediscovered the formula for a white enamel. According to Benton, the white tin-glaze was known in Italy as early as 1400, but did not become the fundamental basis for enamelling until about 1630. In this year, the same authority says, two French enamellers began to decorate small gold objects on a background of white enamel, and the method soon spread to Paris, Dresden and Vienna. Since Palissy had died in Paris but 30 years previously, it seems not impossible that the formula used by the Frenchmen was based on his discovery of a white tin-glaze for pottery.

In the years that followed, the art of enamelling developed gradually alongside the sister arts of glass-making and ceramics. New materials and methods discovered at one place were soon shared or imitated by groups of craftsmen at another. Centres of industry were established in Italy, France, Germany and Holland, and eventually in England.

At about the same time that Wedgwood was starting on his career in Staffordshire, Theodore Janssen opened his factory at Battersea for the manufacture of enamelled curiosities. This was in 1750, and was the first time that enamelling on any considerable scale had been attempted in England. The business failed after six years, and was never restarted. Enamelling was continued for a time at Bilston and also at Birmingham, and it seems certain that some of the skilled workpeople thrown out of employment at Battersea moved to Staffordshire. These early English enamels consist of white enamel on copper, and are peculiar for their decoration by means of transfer-printing. The workmanship is excellent, and the enamelling and decoration remarkable.

Thus it happened that when enamelling on iron was begun in Birmingham in 1830, the early experiments of potters, enamellers and glass-makers alike had put to hand much special knowledge that was needed. Cobalt-blue had been discovered by Christoph Schürer, a Saxon glass-blower in the 17th century, and has played an important part in the sheet industry. Felspar, fluorspar and china clay—raw materials of the potter—became important ingredients in enamellers' recipes, and the tin-glaze of the Bilston and Battersea toymakers took on the new distinction of "cover-coat."

By the time 1900 is reached it is found that in the hollow-ware, sign and foundry trades, enamelling on iron was firmly established. Without any exact knowledge of scientific principles, practical men had advanced the industry by patient experience and determination. Austria and Germany led the world in this respect. A writer in "The Engineer" of 1901 says:—"The enamelling industry which at one time gave promise of becoming one among the many large manufacturing interests in England, has fallen short of expectations. This can readily be accounted for. England and Englishmen in their protection of "secrets" have long been distinguished by their conservatism, and the enamelling industry is no exception. The process is known to a few and strictly guarded, and as profits are satisfactory, enamellers are content to go on without change and without effort to pierce the prospects of the future. In Germany and Austria manufacturers are induced to take intelligent apprentices, and theoretical instruction is provided in the technical schools. English enamels are not inferior in quality, but Germany and Austria undersell us by 25 per cent. In no part of continental Europe is English hollow-ware to be found, and in our colonies the same fact exists. Austrian works financed by German capital supply nearly the

(*Courtesy of Victoria and Albert Museum.*)

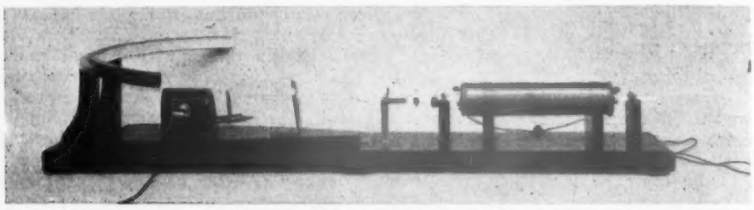
FIG. 2.—EARLY ENGLISH ENAMEL. *Top*: Bilston tea-caddies and (*bottom left*) sugar canister about 1760. *Bottom right*: Battersea toilet-box, 1750.

* Paper read before the Southern Section of the Institute of Vitreous Enamellers.

whole of India's requirements. All this goes to prove how indifferent our manufacturers have been to the improvement of an industry which might have found profitable use for a large amount of capital and for a great number of the unemployed of our workpeople."

### Foreign Research Work

To some extent a similar criticism may be made to-day. America leads the world in opening up fresh markets for enamelled goods, and in supplying high-quality materials for their manufacture. Mass-production requires new methods of control, and a thorough understanding of the fundamentals of the process. Apart from the excellent Paper on enamel adhesion by Dr. White, there is little evidence that much research in this field is being done in Great Britain. In this respect this country lags behind the other great nations of the world. As far back as 1909 Germany had begun to follow up her brilliant lead in glass research by a physical investigation of the properties of commercial enamels, and since the War the Polytechnics at Karlsruhe and Darmstadt have contributed generously to the knowledge of enamelling.



*(Courtesy of Research Laboratories of General Electric Company, Limited.)*

FIG. 3.—EXPANSION APPARATUS.

In the United States at about the same time the University of Ohio stimulated an interest in acid-resisting enamels for sheet iron which has been followed up with all the imagination of American chemists. Since 1909 more than 100 Papers describing original investigations on vitreous enamels have been contributed to the American Ceramic Society by the research organisations of the United States. In Japan since the War studies of enamelling have been made at the Imperial Research Institute at Osaka, and one report alone gives the results of measurements on two thousand different compositions of frit. In Russia, too, enamel research is being carried on at the Ceramic Research Institute at Leningrad.

That to-day the home industry shows promise of better times ahead is undoubtedly due in part to the efforts the Institute are making to awaken a new consciousness amongst enamellers. Thanks are due to Mr. James Gray, who first succeeded in bringing the trade together in 1934. Last year, in collaboration with the British Cast Iron Research Association, the Institute began an experiment in co-operative research, which is having good effects, and there is much investigation to be done which requires the united efforts of the whole industry. At the same time it is important that individual firms should encourage research by giving employment as far as possible to trained men from the Universities.

British Universities do not generally turn out ready-made specialists in vitreous enamelling, but believe a sound knowledge of natural science is the basis of most industrial processes. Lord Nuffield must have felt this when recently he endowed so generously the new laboratory of physical chemistry at Oxford.

When Mr. England addressed the first annual conference of the Institute in 1934 he gave an account of some of the principles which underlie enamelling. In the remainder of this Paper it is proposed to extend the consideration of those first principles, and refer to a few ideas which have occurred in the course of work at National Enamels, Limited. An attempt will be made to indicate where they have led to methods of process control, which was the subject of recent lectures by Mr. Pearce and Dr. Martin.

The substances commonly used in frit manufacture have been described by Andrews, Grünwald and others in their text-books of enamelling. Excepting the inert gases almost every known element has been tried in some form or another as an ingredient of enamels. Since 1900, Patents have been granted to protect the use of beryllium, caesium, lithium, zirconium, and sodium antimoniate in enamel formulæ, and sodium silicate has also been described as a new raw material. Zirconium is becoming increasingly important as an opacifier, but is not generally used in the batch. Sodium antimoniate is widely advertised in the United States, but in this country seems to have made little headway against the cheaper tetroxide. Sodium silicate is useful as a combined form of silica, but again is a relatively expensive material. The other new materials are not used to any extent.

### Titanium Oxide

The history of the use of titanium oxide in the enamelling industry seems interesting. According to a British Patent issued in 1893, partial replacement of silica by titania is recommended to give "an opaque enamel with a large coefficient of expansion, more resistant to the corrosive effects of acids." Apparently this was not immediately recognised, and it was 1920 before any considerable information on titanium enamels was published. Although during the last six years these enamels have entirely replaced the old formulæ for cast iron, titanium is not extensively used in this country for sheet iron enamels.

It is reported from Germany that successful attempts have been made to reduce the quantity of borax used in enamel mixes—an advantage to a programme of self-sufficiency. This was referred to in the exchange Paper which Dr. Karmaus presented to the Southern Section of the Institute of Vitreous Enamellers two years ago, and was the subject of an American Patent in 1918. How it is an economic advantage it is difficult to understand. It is known that some boric oxide may be lost in the process of smelting, and Dimbleby and Turner recommend that in the fusion for analysis of glasses containing more than 10 per cent. of boric oxide, free silica should be added to prevent volatilisation, but how the replacement of two-thirds of the borax content of the mixture by an alkali borosilicate glass effects anything other than an increase in cost of production, is not easy to understand.

The substitution of dehydrated borax is a different matter. At the recent Porcelain Enamel Institute Forum in America, H. D. Carter gave the results of some tests on the effect of dehydrated borax upon the smelting of grey enamel. The saving in fuel costs are quite remarkable.

Mr. England touched on the subject of control of raw materials. An examination of all the substances used by the frit-maker would certainly require the full-time services of an analytical chemist. Usually this is out of the question for the small manufacturer, and he must rely on the good faith of his suppliers. The materials most likely to vary in composition from batch to batch are those obtained from natural sources—felspar, fluorspar, quartz and natural cryolite. Fairly pure cryolite is available, and a good grade of quartz will contain 99 per cent. of silica, but it has been found that fluorspar may contain up to 10 per cent. of silica besides 2 per cent. of lime. Felspar, forming as it does 20 to 40 per cent. of the batch, should be analysed as to every consignment, and a sample examined on a 60-mesh sieve for traces of mica. Landrum has outlined the procedure of analysis of enamel raw materials, and fuller methods are given in the text-books of Mellor, Treadwell, Hillebrand and Lunge, Keane. At National Enamels a point is made of examining the fineness of all ground materials.

The Papers which have been published describing investigations on frit compositions are very numerous indeed, especially in American journals. They fall roughly into two groups. Either an investigation is made of the effect of some particular ingredient on the properties of an enamel, or the ingredients of a given formula are varied systematically and the change of properties noted or measured. Amongst the substances which have been studied separately are cobalt oxide, manganese dioxide, titania, zirconia, antimony, beryllium, sodium silicate, lime, magnesia, barium, lead, the fluorides, and the rare earths.

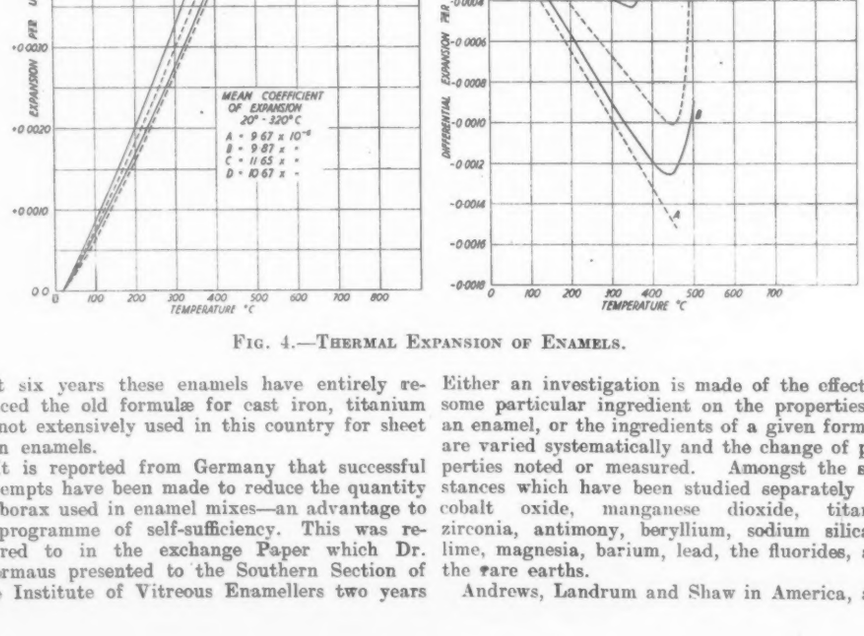



FIG. 4.—THERMAL EXPANSION OF ENAMELS.

Andrews, Landrum and Shaw in America, and

Uchida in Japan are among the more important workers. Sometimes one particular property of an enamel is the subject of a systematic investigation. The work of Mayer and Havas on coefficients of expansion, of Agde and Krause and Andrews on opacity, that of Poste on acid-resistance, and the recent work of the Bureau of Standards at Washington on the viscosities of molten frits are examples. More often different compositions of the batch formula are studied simply for their working properties by making sample plates in the enamel. Sometimes in addition impact or bending tests are made, and frequently tests for acid resistance.

The standard of the work carried out is often not up to the high level of similar investigations in glass technology. Scientific investigation is comparatively new to the enamel trade, and enamellers are frequently unfamiliar with modern methods of research. Moreover, from the scientific standpoint enamelling is a very complex business, and its problems not easily solved. The chemical analysis of enamel frits can be a difficult procedure when constituents like alumina, titania and zirconia occur together with phosphorus and fluorine, and frequently the interpretation of purely physical measurements is well-nigh impossible.

Much can be learnt from the methods of research workers in other industries, especially from the glass technologists. The methods worked out for the analysis of opal glasses are the basis of the chemical examination of enamels, and reference to a book like Morey's "Properties of Glass" at once suggests new ideas for the enamel laboratory.

The importance of a consideration of the coefficients of thermal expansion of enamels has long been understood. The agreement of this property for ground and cover enamels with the thermal expansion and contraction of the metal base is recognised to be necessary for adhesion. Defects in chipping, crazing and fish-scaling can often be attributed to strains set up by change in temperature of the enamel. At first the view was held that cobalt oxide in the ground coats of sheet steel enamels served to adjust their expansion to that of the steel, but this was disproved by Mayer and Havas. From 1909 to 1911 these workers established limits for the expansion coefficients of enamels for sheet steel over the temperature range 0 to 100 deg. C., and at the same time determined factors for the several constituents. These factors are still in use to-day for the estimation of this property. American workers have extended the study by measurements over a range of temperature up to the softening points of enamels, and have also investigated the effect of mill additions. Dietzel and Meures in Germany have demonstrated also that the solution of iron oxide in the ground coat can raise the expansion of the enamel to equal that of the iron.

Mr. Pearce and Dr. Martin referred to the interferometer apparatus for measuring coefficients of expansion. In this country the differential method, whereby the linear expansion of a sample relative to a standard, is more often used. Through the courtesy of the Director of the Laboratories of the General Electric Company, Limited, the writer is able to describe the apparatus used at Wembley, and to give some results of determinations on commercial enamels.

Rods of enamel about 10 cms. long and 3 mm. in diameter are drawn from the frit by melting it in a blow-pipe flame. The specimen is placed on a support in a small tubular electric furnace, and its linear expansion transmitted directly to a silica rod. The movement of the silica rotates a small roller which carries a mirror, and the expansion magnified a thousand times is recorded on the circular scale. The temperature is measured by a thermo-couple placed directly above the specimen.

Fig. 4 gives the results of expansion measurements on four sheet steel enamels. A and B are different batches of the same ground coat enamel, and C and D are different cover-coat frits. The mean coefficients of linear expansion are one-third the coefficients of cubical expansion for the same temperature range. The differential curves represent the difference in length at any given temperature between the enamels and the steel, all of which have unit length at room temperature.

In Table I a comparison is made of the expansion coefficient found for enamel D with the value obtained by using Mayer and Havas' factors.

For some expansion measurements in which the differential principle is used the apparatus is made entirely automatic. The method due to Pellin has been described by Bernard Long. In this apparatus the linear expansion of the specimen is linked by a beam of light to the galvanometer mirror of the temperature indicator, and the expansion-temperature curves are plotted automatically on a photographic plate.

The softening of enamels at moderate temperatures permits them to be fused evenly on the metal, and the working range of the firing process is governed by this property and the character of the metal base. It is important that the fluidity of the enamel during firing should allow the ready escape of occluded air and any gases formed at the metal surface, thus preventing the formation of blisters.

(*To be continued.*)

TABLE I.—*Coefficient of Expansion of Frit Materials.*

| Chemical analysis of frit. | | Revised composition. | | Expansion factors.* | Estimated expansion coefficient. $\times 10^{-7}$. |
|---|---|---|---|---|---|
| Silica | 37.94 | Silica | 37.94 | 0.8 | 30.35 |
| Antimony trioxide | 11.98 | Antimony pentoxide | 13.30 | 3.6 | 47.88 |
| Ferric oxide | 0.13 | Ferric oxide | 0.13 | 4.0 | 0.52 |
| Titanium oxide | 4.50 | Titanium oxide | 4.50 | 4.1 | 18.45 |
| Phosphorus pentoxide | 0.64 | Phosphorus pentoxide | 0.64 | 2.0 | 1.28 |
| Alumina | 2.43 | Alumina | 2.43 | 5.0 | 12.15 |
| Zinc oxide | 4.12 | Zinc oxide | 4.12 | 2.1 | 8.65 |
| Barium oxide | 1.19 | Barium oxide | 1.19 | 3.0 | 3.57 |
| Lime | 3.00 | Lime | 0.76 | 5.0 | 3.80 |
| Sodium oxide | 15.05 | Sodium oxide | 10.45 | 10.0 | 104.50 |
| Potassium oxide | 0.98 | Potassium oxide | 0.98 | 8.5 | 8.33 |
| Boric oxide | 13.62 | Boric oxide | 13.62 | 0.1 | 1.36 |
| Fluorine | 4.34 | Calcium fluoride | 3.12 | 2.5 | 7.80 |
| | | Sodium fluoride | 6.23 | 7.4 | 46.10 |
| Loss at 500 deg. C. | 0.30 | Loss at 500 deg. C. | 0.30 | | |
| Sulphur trioxide | 0.19 | Sulphur trioxide | 0.19 | — | — |
| Total | 100.41 | | 99.90 | | 294.74 |

Measured mean coefficient, 20–100 deg. C. = $281.4 \times 10^{-7}$.

* "Enamels," by A. I. Andrews, 1st Edit. (1935), p. 40.

# Foundry and Enamel Practice as Applied to Cast Iron

## By GEORGE M. LOGAN

(*Concluded from page* 370.)

### Enamelling Shop Practice

Enamelling operations will depend on the types of articles to be enamelled, the use to which they will be put, and the standard by which they will be judged: (1) appearance; (2) resistance to chemical action; (3) resistance to sudden change of temperature; (4) resistance to prolonged heating at various temperatures below the fusing point; (5) resistance to shock; and (6) resistance to abrasion. For example, enamels for sanitary wear will be applied by the dusting process, and will require to have a good appearance, and be able to withstand the action of soaps and dilute alkaline solutions. Enamels for chemical use will require to have the maximum of resistance to acid or alkali, and be free from such defects as pinholes, cracks, and foreign matter. Appearance (opacity, for example) is only of secondary importance. Cooker hobs will require to have a good appearance and ability to withstand the action of fruit juices, be resistant to sudden changes of temperature, have a high fusing-point to prevent the enamel softening should local overheating take place, and have a hard surface to withstand abrasive action.

The factors controlling the finish and durability will depend on:—(1) enamel composition, both chemical and physical; (2) composition of the metal; (3) treatment of the metal prior to enamelling; and (4) application and firing of the enamel. It is essential for the successful enamelling of cast iron that the enamel constituents be controlled within well-defined limits, and these limits are governed by the firing temperature, the chemical and physical properties of the enamel and the metal. The application of the enamel to the metal has to be carried out from a low red heat to a bright red heat, and the enamel must be capable of adhering firmly to the metal without chipping, crazing, or pinholing; in many cases it must be able to resist chemical action. It must also give the desired finish, be durable and, at the same time, economic to work. It is not only essential that the enamel itself should be correct in its composition, but the metal to be enamelled, and its treatment before and during the enamelling process, should also be well controlled and supervised at the various stages.

For a study of the working properties, it is desirable to classify enamels into three classes, viz., soft, medium and hard. The type of enamel demanded will depend for its composition on what it is required to withstand while in use, and whether it has to be applied by the liquid or dry process. The enameller will not get all that is to be desired in any one enamel, so he must compromise.

First, soft or easily-fired enamels combine low fusibility and a good gloss, but they are, as a rule, not resistant to chemical action or weathering, although they have the advantage of being easily worked. The medium-fired enamels, as compared with soft ones, have improved resistance to chemical action; a good gloss can be maintained, and they are still comparatively easy to work. The hard-fired enamels, in which category enter acid-resisting and alakali-resisting enamels, are much more difficult to fire and

work; consequently, much greater care has to be taken throughout the entire process, the objective in each case being to produce on the castings a smooth enamel layer free from defects.

To do this the enameller is confined to definite limits of temperature during the firing process, and these temperatures are governed by the enamel compositions and the process employed, the firing range for all types falling between 700 and 930 deg. C. In the low-temperature range (from 700 to 800 deg. C.) there are the ordinary enamels used in the liquid process. In the medium range (from 800 to 900 deg. C.) are dusting enamels as used for baths, etc. In the high-temperature range (900 to 930 deg. C.) are acid-resisting enamels used in the dusting process.

To process them successfully, the castings must be of good quality, properly prepared, and the enamel must be suitable for the purpose. Correct firing will depend on the temperature, duration of firing, uniform heating, proper support, and correct muffle atmosphere. With soft or low-temperature firing enamels, there is the advantage that the articles to be enamelled are not so liable to be distorted, but the durability, as a general rule, is not so good. When one enters the region of 900 deg. C. for firing, considerable care must be taken, for there is a liability of distortion of metal, and chipping, crazing and pinholing are much more prone to take place. For successful enamelling, it is necessary that processing should be done in all cases below 930 deg. C.

### Wet-Process Enamels

Wet-process enamels are used largely on lightweight ware, being applied by spraying after the castings have been thoroughly annealed and blasted. They may be lead or leadless, and applied either directly to the metal or on top of a ground coat. Castings to be enamelled by this process, particularly in the absence of a ground matt coat, should possess, as they come from the mould, a good smooth skin, free from small pits or cavities caused by coarse sands or unsuitable facings, and there should be an entire absence of sand burnt into the surface of the casting.

If a start is made with a rough pitted surface on castings prior to blasting, there is a considerable risk of producing defective ware, as it is very difficult to eliminate entirely burnt-in sand, or to remove the facing from cavities, even with efficient and prolonged blasting. Dependable results can only be obtained by ensuring that each part of the process, from the metal to the enamelling, is carried out with the proper precautions.

It is sometimes thought, because the surface of the metal is cleaned and roughened by the shot-blast process, that it is unnecessary to have a smooth surface prior to blasting. This is not the case, however, as the roughnesses produced are not alike. Starting off with a good surface, shot-blasting yields a surface resembling emery paper to the touch, and more or less porous in character, whilst the cavities are inclined to regularity and uniformity. In the other case, there is an irregular coarse surface with projections and indentations, non-porous in character, which is difficult to clean thoroughly, so that the roughness produced by the blasting is superimposed on top of this other coarse, irregular rough face. In such cases, before the castings are blasted, extra dressing or filing has to be performed, and anything saved in the moulding operations is more than outweighed by the additional cost involved to improve the finish. Even then the production of defective or second-class ware is increased.

The fusion temperature is usually in the region of 740 deg. C. for ordinary wet-type enamels. Acid-resisting enamels will require higher temperatures. The duration of firing will depend on the weight and thickness of the castings charged into the furnace—the average time being from 15 to 20 minutes.

### Ground Coats

Ground coats are usually of the matt variety, and, when used, two or more firings have to be given. Articles so treated are less liable to blister, but are more prone to chip or flake off. With castings such as cooker hobs which have to be subjected to high temperatures while in use, it is sometimes advisable to apply a matt ground coat, as this acts more or less in the nature of an insulator. An enamel applied by the liquid process direct on to the metal might fail in this test, but the same enamel applied over a matt ground coat might be entirely satisfactory. The disadvantage of the latter is its liability to chip, and its inability to withstand mechanical shock.

TABLE I.—*Firing Test using Wet-Process Enamel on Plates of Increasing Thickness.*

| Plate thickness. In. | (1) C. C before annealing. | (1) Difference between | (2) C. C after annealing.* | (3) C. C after annealing and firing of the enamel. |
|---|---|---|---|---|
| | Per cent. | | Per cent. | Per cent. |
| A. $\frac{1}{4}$ | 0.407 | A & B = 0.008 | 0.136 | 0.089 |
| B. $\frac{5}{16}$ | 0.399 | | 0.123 | 0.087 |
| C. $\frac{7}{16}$ | 0.385 | B & C = 0.014 | 0.117 | 0.083 |
| D. $\frac{1}{2}$ | 0.355 | C & D = 0.030 | 0.125 | 0.081 |
| E. $\frac{3}{4}$ | 0.286 | D & E = 0.069 | 0.112 | 0.081 |

* Annealing period was the time taken to raise the plates to 800 deg. C., plus an additional 5 minutes.

When the enamel is applied, the aim should be to get the metal and enamel to come into conformity with one another, or, in other words, to have sufficient heat to oxidise the surface of the metal to the required point, and thereafter the enamel should fuse quickly to seal the metal and get good adhesion. If it fuses too readily, it does not give the necessary time to oxidise the metal surface; on the other hand, if it does not fuse quickly enough, over-oxidation of the metal will take place, and in both cases bad adhesion and trouble will result.

The better the bonding power, assuming that the enamel is not too thick, the greater it will be able to resist shock and sudden change of temperature. When castings are not uniform in thickness, and especially if these thicknesses vary considerably, it is impossible to heat them up uniformly, and the enamel on the thin parts will mature more rapidly than on the thick parts; hence, unless the enamel has a good working range and the correct temperature is used for firing, one is liable to get blistering or boiling of the enamel.

In order to test this, some experiments were made on plates of normal analysis of different thickness. After annealing they were given one coat of white enamel applied direct to the iron. The plates used were $\frac{1}{4}$, $\frac{5}{16}$, $\frac{7}{16}$, $\frac{1}{2}$ and $\frac{3}{4}$ in. thick, and had been cast in the usual manner and were tested for combined carbon prior to annealing. The results are set out in Table I.

In column No. 1 of Table I the combined carbon decreases as the thickness increases, and the decrease is doubled in each successive plate from A to E; in column No. 2 the plates A to E again show a successive decrease with the exception of D, whilst in column No. 3 the same tendency is shown as in column 2. On comparison of columns 2 and 3, the combined carbon is lowest in column 3, showing that the annealing time was insufficient and that the annealing process was completed during the enamelling process, and although this process was still going on during the firing of the enamel, it did not cause blistering or boiling in the $\frac{1}{4}$-in. plates, and the blistering was practically overcome in all plates when the temperature was reduced to 720 deg. C.

The enamel used was an ordinary normal working enamel. In No. 4 (Table II) range of plates only the $\frac{1}{4}$-in. one was free from blisters after enamelling. All the others showed it in increasing amount as the thickness of the plates increased. In No. 5, the $\frac{1}{4}$-in. plate was free, the $\frac{5}{16}$-in. plate only slight, and the remaining three pronounced, although much better than the corresponding plates in No. 4 range. In No. 6 range, only the two heaviest plates had a slight trace of it, whereas similar plates in ranges 4 and 5 had blistering all over the surface; and No. 4 was much worse than No. 5. From this it will be seen that it is important with castings of uneven thickness that the temperature for enamelling should be thoroughly controlled, and if blistering does occur, a lowering of the temperature will probably cure the trouble provided the enamel used is of the medium or soft variety. With hard enamels or those difficult to fuse, it is necessary in some cases to increase the firing temperature, but the object in both cases is to get the enamel and iron into conformity with each other, so that the enamel does not mature before the casting has reached the furnace temperature.

### Pinholing

Other instances of pinholing may be due to insufficient burning of the ground coat, for too short a period or at too low a temperature. Spongy cast iron is another cause, and this is commonly found in the neighbourhood of the gates; in cases of this kind sand is often found baked into the iron and not removed by blasting. Also, there will be a difference in analysis between the spongy part and the sound part of the casting, the former being lower in silicon and higher in total carbon, manganese and phosphorus. Manganese sulphide will also cause pinholing or blistering if the castings are allowed to remain too long in the mould. The moisture in the sand converts some of the sulphide to sulphate, causing local hard spots on the surface of the casting which are difficult to remove by blasting.

TABLE II.—*Result of Test Plates after Annealing at 800 deg. C., then Enamelling and Firing with One Coat White at the Different Temperatures.*

| Furnace temp. | (4) 780 deg. C. Duration of firing. Mins. | (4) Blistering. | (5) 750 deg. C. Duration of firing. Mins. | (5) Blistering. | (6) 720 deg. C. Duration of firing. Mins. | (6) Blistering. |
|---|---|---|---|---|---|---|
| Plate A, $\frac{1}{4}$ in... | 10 | Nil | 13 | Nil | 16 | Nil |
| ,, B, $\frac{5}{16}$ in. | 12 | Slight | 15 | Slight | 24 | ,, |
| ,, C, $\frac{7}{16}$ in. | 14½ | Pronounced | 20 | Pronounced | 25 | ,, |
| ,, D, $\frac{1}{2}$ in... | 14½ | Bad | 20 | ,, | 25 | Very slight |
| ,, E, $\frac{3}{4}$ in... | 21½ | Very bad | 24½ | ,, | 28 | ,, ,, |

Bad shot-blasting will also cause pinholes, due to several reasons, such as incomplete removal of sand or facing materials, and the presence of oil or water in the air for blasting. All castings after blasting should be thoroughly blown with dry air to remove loose dust from the surface. Casting the metal at too high a temperature will also cause blistering. It should be run hot from the cupola, but poured at a lower temperature, and should "stand-up" well. If cast too hot, there is a liability to get fine sand burnt into the pores of the iron; after

# BLYTHE RELIABILITY

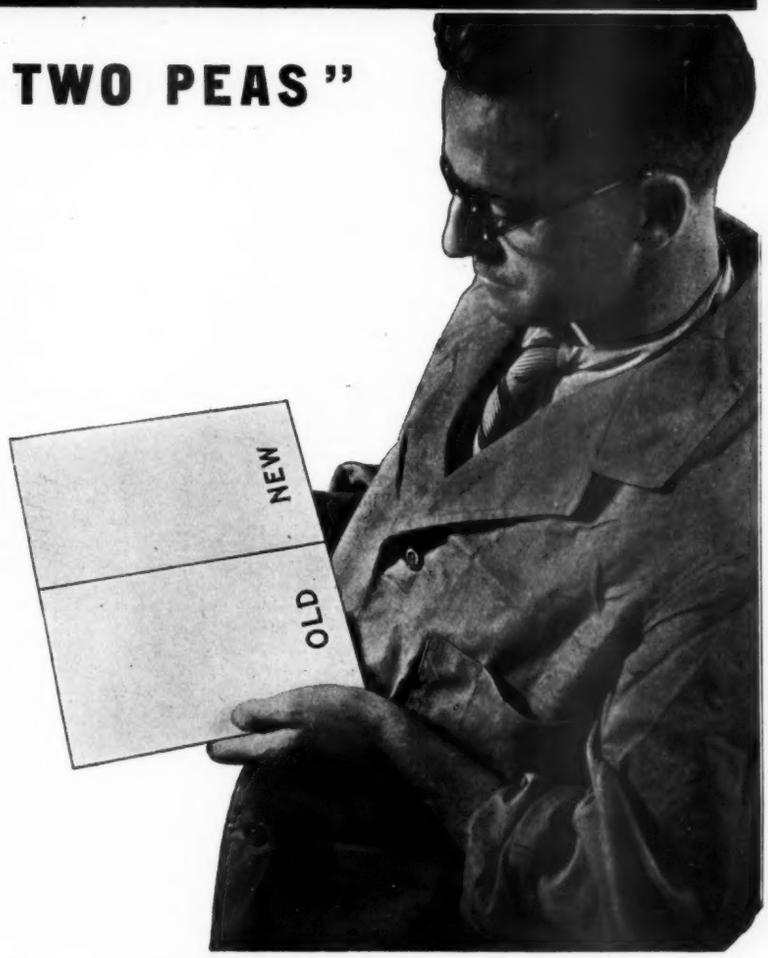
## "AS LIKE AS TWO PEAS"

One of our enamelling staff comparing the result of a fired sample of a new batch of enamel alongside the standard. We file a specimen of every batch and thus have a practical record always at hand.

The result must be "as like as two peas," because every consignment we send out has to match the filed sample for colour, gloss, uniformity and quality before being released.

From every batch we fire a sample under exactly the same conditions as in your own works.

Not until an identical match is certified does an ounce of material leave our works.



Blythe

OXIDES, ENAMELS & MATERIALS

BLYTHE COLOUR WORKS LTD.

CRESSWELL · STOKE-ON-TRENT

R2a

blasting the iron may appear clean, but the fine sand can be seen with the aid of a microscope. This defect will be aggravated when there are heavy parts on the castings, such as bosses or snugs.

Uneven muffle temperature will also cause trouble. It may be that the bottom-heat is below the average and the top-heat above it, so that the enamel is maturing more rapidly than it should, and the casting less than it should. The result is blistering and bad adhesion.

### Sand and Surface

Generally speaking, the surface condition of the castings prior to shot-blasting has a very strong influence on the success of the enamelling operations, and will depend on the porosity of the surface, brought about by the fineness of the moulding sand used on the mould face, and the casting temperature. All sands will produce porosity or indentations, the extent of which depends on its coarseness or fineness, and the cavities produced from the sand grains are pockets or beds into which the sand can be baked, and to which the blasting process has not free access. Very soft irons carrying high silicon and graphite will also result in a surface more or less porous, producing the same effect as in the previous case. In order to test this, samples were filed entirely to remove the original surface, and it was found that blistering did not take place even without annealing or sand blasting.

During the firing of the enamel, any sand or siliceous matter adhering to the surface of the metal begins to react with the enamel during firing, but the temperature is too low and duration of firing insufficient to complete the reaction, and the consequence is blistering. Similar action is taking place at the same time with the iron-oxide formation during the firing; it is really a dissolving action, and is responsible for the bond between the iron and enamel. With this double reaction, the more violent it is, the greater is the liability to blistering or boiling.

It may be asked why small sand grains should cause this trouble, and why a matt ground coat, which is highly siliceous, should not increase but eliminates the trouble. The two conditions are quite different. In the case with sand grains on the surface, it is a question of applying and firing on direct a fusible enamel which will react readily with the siliceous material and oxide of iron, causing a comparatively violent action. The second case is one of working an enamel or ground coat hardened up with silica or siliceous material which merely sinters together and does not fuse. It is then subjected to firing at a temperature below fusing point before the application of the easily-fusible cover enamel, so that the action in the firing of the ground coat is much less violent and has been completed before the application of the cover enamel. Matt ground coats during firing should not be burned at too high a temperature, otherwise glazing or fusing may occur, depending on the composition, and the more the glazing takes place, the greater will be the tendency to blister.

### Dry-Process Cast-Iron Enamels

In the dry process, two methods are employed: (1) the rolling process and (2) the dusting-on process. In the rolling process, a very soft or easily fusible enamel is used, and the articles to be enamelled are usually small and of fairly heavy section. The practice is to shot-blast and ground-coat the pieces. Next, they are fired at from 850 to 900 deg. C., and when the ground coat has matured the castings are withdrawn individually and plunged into a container filled with the powdered enamel. The casting is held by a pair of suitable tongs and is worked backwards and forwards to get the enamel to cover it completely and to give sufficient thickness. It is then taken out and placed on the table, and the casting will have sufficient heat in it to melt and run the enamel to the desired smoothness, provided the enamel is sufficiently soft. This process for small castings of suitable thickness is cheap and economical to work, and the percentage of rejects is low. The furnace must be small and the articles easily handled, to get the maximum efficiency at the minimum cost.

### Dusting Process

The dusting process is applied chiefly to heavy castings, or castings of complicated design. It is applied to baths, hand basins, and vessels for chemical use. A ground coat is invariably used, and the average firing temperature lies within 820 to 900 deg. C. Castings to be enamelled by this process should be of suitable composition, and while it is always advisable to have them well finished and free from defects, it is not so essential as in the wet process. The main points of control are metal composition; thickness and composition of enamel; firing temperature, and freeness from defects.

In connection with metal composition, when making up a cupola charge for castings such as baths, care and discretion must be exercised in the choice of irons so that the maximum strength can be obtained; at the same time, the iron with which the castings are made should be as soft as possible. The fundamental principles applying to castings for wet process also apply to castings by the dusting process. A suitable composition is:—T.C, in the region of 3.5; C.C, not to exceed 0.4, or at most, 0.45; Si, 2.5 to 2.7; Mn, 0.6 to 0.8; S, as low as possible, and P, 0.8 to 1.0 per cent.

The aim should be to keep the combined carbon as low as possible under 0.4 per cent., and definitely not in excess of that figure, otherwise trouble is liable to occur in the foundry and enamelling shops, due to breakage and warping. It is important that the moulds should be well rammed, and castings such as baths should be weighed in the dressing shop prior to enamelling to see that they do not exceed a definite percentage over the pattern weight. They should also be examined by reflected light in order to show up the softly-rammed parts. If these be very pronounced, the castings should be rejected; otherwise a wavy or lumpy enamelled bath results. If the castings have to be enamelled without shot-blasting, the metal and enamel must be controlled within well-defined limits, as castings treated by scouring only are much more liable to develop chipping, crazing and shivering of the enamel, due to the weaker bond between the enamel and the iron, and in this connection the mould facings play an important part.

### Facings

Various types of facings are used on the moulds, the chief being plumbago, blacking, terra flake, quartz, etc. If the castings have to be shot-blasted, any of these can be used quite successfully. If, however, they do not require to be blasted, plumbago, terra flake and quartz should be ruled out, the last two particularly if the percentage is high when mixed with blacking. The reason is that they are very difficult to remove from the surface without blasting, and consequently are liable to give bad adhesion and cause "shivering" of the enamel. When castings are not blasted, the oxide film is not removed, with the result that, during firing, this film increases in thickness and unless every care is taken to control it, it becomes too thick and the enamel has poor adhesion.

The composition of the metal and enamel must also be closely controlled to get the correct coefficient of expansion and contraction; it is possible to adjust the one or the other by an alteration to the composition. Should the iron decrease in silicon from, say, 2.7 to 2.4 per cent., shivering or crazing may occur, but this can be rectified by adjusting the silica content of the enamel. The other point of control is the temperature and duration of firing, care being taken to see that the ground coat is not too thin and that it is not overburned when firing it.

When firing the ground coat on castings which are not blasted, there will be a considerable boil, due very largely to incomplete removal of the mould facing from the castings, but this boil can be removed if the castings are taken from the muffle after the grounds are properly fused, and exposing them to the atmosphere for a few seconds before returning to the furnace. After this, the enamel is applied in the usual manner, and the operation repeated until the desired finish is obtained. With castings subjected to shot-blasting, considerably more latitude is obtained, and the amount of care given in the previous case is not so necessary. There will be wider limits with the metal and enamel compositions, and mould facings, and the enameller does not require to be so expert. As against this, the castings will have more surface defects brought out in the blasting (which require to be filled), and there is a tendency to get a wavy enamel surface unless good care is taken that the ground coat is evenly applied and free from ripple. Enamel applied on the top of a ripply ground coat will show up in an exaggerated condition in the finished enamelled casting, especially on perpendicular surfaces, due to the irregular reflection of the light.

### Dusting Enamels

The enamels used in the dusting process for such articles as baths, basins, etc., are much more complicated in composition than those used in the wet process, and all, or nearly all, the opacifying agents are added before melting the raw batch. The amount of enamel or thickness of the enamel on the castings is also greater and not so uniform; consequently, they are more liable to crazing or chipping than those of the wet process. Troubles commonly encountered in dusting or dry-process enamels are chipping, crazing, pinholing, and black specks.

Chipping and crazing are controlled by suitable adjustment of the composition of the metal, enamel and correct firing temperature. These faults are caused by internal stresses or strains, introduced prior to the enamel application, and result from the tendency of the materials to expand and contract, both of which occur in the metal and enamel, and are the result of unequal temperature or different expansions of metal and enamel.

Pinholing and blisters can be caused by cavities in the castings, slag in the metal, insufficient firing of the ground coat, carbonaceous matter in the enamel, bad practice in the manufacture of the enamel, and rust in the iron.

Black specks can be caused by bad melting practice in enamel manufacture through using too strong an oxidising or reducing atmosphere in the melting furnace, or by dirt getting into the enamel during the grinding or running-off operations, or during the application of the enamel. Where the opacity is not very good, black specks are immediately shown up, but if the opacity is strong, the trouble is not nearly so pronounced. It is essential in the manufacture of enamels of this type that the utmost care be exercised during the entire process to prevent contamination.

For dry-process work considerable skill has to be exercised by the individual workmen during the application and firing of the enamel to secure even distribution of the enamel, and to humour the casting if it is of unequal thickness, thereby avoiding ridges or beads of enamel.

### Conclusion

The main points of control for wet-process enamelling are:—Suitable metal composition and good melting practice; castings with a good smooth skin, free from cavities and surface defects; thorough shot-blasting; and correct firing temperature.

For dry-process work, the main points are:—Suitable metal composition and melting practice; castings to be free from defects, but not to the same extent as for wet-process work; shot-blasting is to be recommended in all cases, but it does not require to be so thorough as in the wet process; and much more skill is required by the individual enamellers.

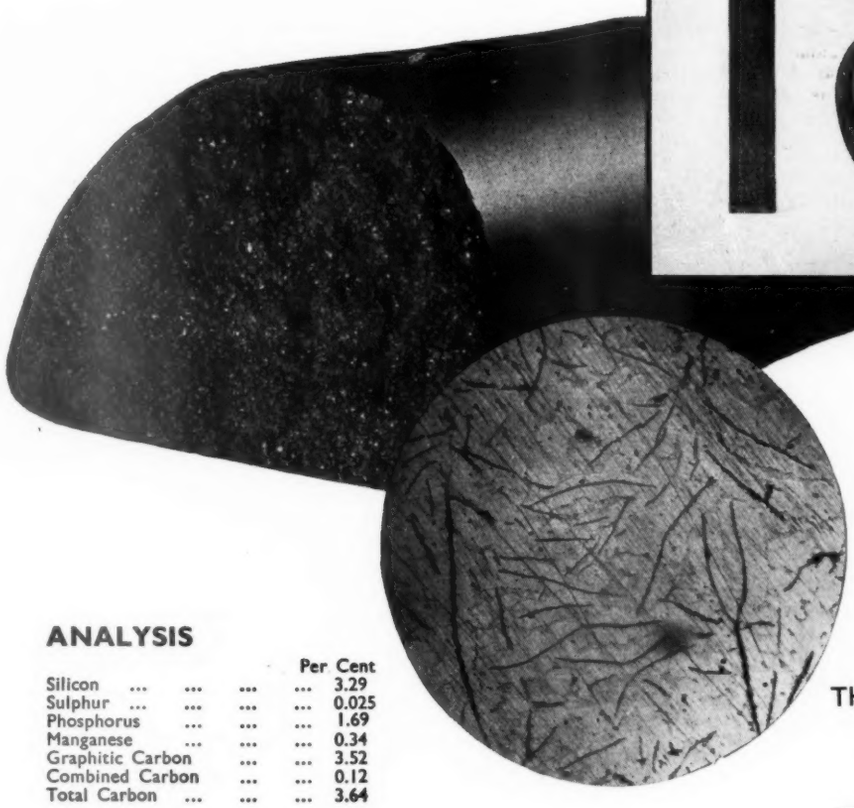
# Light Castings need a *Fluid* Iron!

A free-running fluid iron is essential to produce clean, sharply-moulded light castings such as Rainwater pipes, Drain pipes, Builders' Hardware, Baths, Stoves, Gas and Electric Fires, etc. The relatively high phosphorus content of Rixon's (W'bro'.) No. 3 Foundry Iron ensures the necessary fluidity for this class of work.

Rixon's (W'bro'.) Irons are produced in two modern furnaces solely for the open market.

**Fluidity Test**

The illustration shows a typical spiral cast with a mixture containing Rixon's Iron. The feed to the spiral was only $\frac{3}{8}$-in. diameter.



**ANALYSIS**

| | Per Cent |
|---|---|
| Silicon ... ... ... ... | 3.29 |
| Sulphur ... ... ... ... | 0.025 |
| Phosphorus ... ... ... | 1.69 |
| Manganese ... ... ... | 0.34 |
| Graphitic Carbon ... ... | 3.52 |
| Combined Carbon ... ... | 0.12 |
| Total Carbon ... ... ... | 3.64 |

THE STANTON IRONWORKS COMPANY LIMITED
NEAR NOTTINGHAM

*The largest producers of Pig Iron (for Sale) in Great Britain*

# RIXON'S (W'BRO') No. 3 Foundry Iron

# The Week's News in Brief

## Trade Talk

THE ANNUAL GENERAL MEETING of the British Standards Institution will be held on June 15 at the Dorchester Hotel, Park Lane, W.1.

THE NORTH BRITISH LOCOMOTIVE COMPANY, LIMITED, Springburn, Glasgow, has received an order from the Government for 50 tanks.

ACCORDING to a message from Istanbul, a contract has been signed with the Metropolitan-Cammell Carriage & Wagon Company, Limited, acting for a British group, for the supply of 300 large-capacity wagons for the Turkish State Railways.

IN FACE of keen competition from Germany, Mavor & Coulson, Limited, mining-machinery engineers, Glasgow, have received the biggest portion of a contract for salt cutters which has been placed by the Government-controlled salt mines of Rumania. Mavor & Coulson are to supply five Samson cutters.

THE STAVELEY COAL & IRON COMPANY, LIMITED, have opened an office in Cardiff, to which is attached a stockyard from which immediate delivery of all descriptions of cast-iron pipes and specials can be effected. The address is G.W.R. Gabalfa Sidings, Mynachdy Road, Cardiff. The representative is Mr. H. J. Stairns.

AT a dinner held during the spring meeting last week of the British Ceramic Society, the Master Cutler (Mr. A. J. Grant) emphasised the importance to the steel industry of research into refractories. He said it was of the utmost importance that there should be the closest possible co-operation between their respective industries. In Sheffield it was the refractories section which was of greatest interest to them, and it was perfectly true that without these materials modern steel-making would be impossible. They were continually wanting to work at higher temperatures, but without the research which was being given to ceramic technology this would be impossible. The Department of Applied Science at Sheffield University had always been most active, and he thought he could justly claim that the large Sheffield firms were showing by their support that they realised the importance of intensive research. The speaker concluded by paying a tribute to Mr. W. J. Rees, who, he said, had carried on most valuable research work in the Applied Science Department.

IN VIEW of the decision of the Government to create a Ministry of Supply, the Federation of British Industries has decided to set up a special committee for the following purposes: (*a*) To consider the terms of the Ministry of Supply Bill and the effect which the proposals contained in it may have upon industry; (*b*) to place its services at the disposal of the Minister of Supply in the event of his desiring to obtain the views or assistance of organised industry on the problems facing him; and (*c*) to act as a channel by which the views of the F.B.I. can be made known to the Minister of Supply on matters falling under his jurisdiction. The committee has been constituted as follows: Lieut.-Col. Lord Dudley Gordon, D.S.O., President of the British Engineers' Association, and chairman of J. & E. Hall, Limited (Chairman); Sir Clive Baillieu (director of the Imperial Smelting Corporation and of the British Metal Corporation); Mr. A. C. Macdiarmid (chairman of Stewarts and Lloyds, Limited); Mr. J. G. Nicholson (Imperial Chemical Industries, Limited); Mr. F. R. M. de Paula (Dunlop Rubber Company, Limited); Mr. J. C. Hanbury Williams (Courtaulds, Limited); Sir William Larke (director of the British Iron & Steel Federation); Mr. Guy H. Locock (director of the Federation of British Industries), and Dr. E. C. Snow (United Tanners' Federation).

OVER sixty members of the Manchester Association of Engineers, under the leadership of Mr. T. Makemson (secretary), visited the Park Works of David Brown & Sons (Hudd.), Limited, Huddersfield, the well-known gearmakers, on Saturday, May 20. The guests, including Prof. Dempster Smith (ex-President of the Association) and Mr. F. Carleton Anderson (Vice-President), were received at the works by Mr. A. Greenwood, Mr. J. Ingham, the firm's representative in Lancashire and Cheshire, and various departmental heads, and they followed a planned route through the works lasting over two hours. As the firm is working to full capacity, the visitors were afforded the opportunity of seeing a wide variety of interesting jobs in course of manufacture, such as large double- and triple-helical mine winding gears for South Africa; ships' propulsion gearing and auxiliary drives, rolling-mill pinions and units, automobile drives, railcar gearboxes and hundreds of various gears and gear units in all sizes—for as many applications—for use both in this country and abroad. The visitors were impressed by the size of the tool room and the accurate and important work carried out there in the manufacture of profile-ground hobs and cutters, generating racks, jigs and patent adjustable floating reamers for use not only in the David Brown works, but also for outside sale. Tea was served in the works' staff canteen, and Mr. F. Carleton Anderson proposed a vote of thanks on behalf of the Association, to which Mr. A. Greenwood responded on behalf of the company.

## Personal

MR. D. W. L. CARVILL has been appointed to the London board of the Steel Corporation of Bengal, Limited, in place of Mr. H. P. Martin.

MR. THOMAS LEISHMAN has retired after nearly 50 years' service with the Carron Company, 38 years of which he was in the cashier's department. At the time of his retiral he was assistant cashier. He received a presentation from his colleagues.

MR. N. F. PARKER, A.I.C., who has just joined the board of directors of J. F. Stewart & Company, Limited, manufacturers of Escol enamels, of Tooting Junction, London, S.W., actually started his industrial career with that company, the founder (Mr. Thomason) being his father-in-law. Mr. Parker received his early education at the City of London Schools, and whilst at Cambridge University from 1919-1923 studied chemistry. He graduated with first-class honours in the Natural Science Tripos. After a year with his present concern, Mr. Parker joined the staff of Humphreys & Glasgow, Limited, and was appointed to the board of that company in 1936. He resigned in 1938 in order to devote his entire attention to the manufacture and development of Escol enamels.

MR. N. F. PARKER, A.I.C.

### Will

HAZLEWOOD, G. F., managing director of Hazlewood & Dent, Limited, makers of engineers' tools ... ... £3,135

## Obituary

THE DEATH has occurred of Mr. J. R. Henderson, a director of Bertrams, Limited, paper mill machinery manufacturers, of Edinburgh.

MR. J. M. TURNOCK, of Port Talbot, who died on May 24 at the age of 71, was for many years a director of the Port Talbot Steel Company, and on its amalgamation with Guest Keen Baldwins Iron & Steel Company, Limited, he became commercial manager of the company, retiring a little over a year ago.

WE REGRET to announce the death of Sir George H. Kenrick, an ex-Lord Mayor of Birmingham and a director of Archibald Kenrick & Sons, Limited, West Bromwich, ironfounders and hollow-ware manufacturers. Sir George, who was in his ninetieth year, will always be remembered for his munificent gifts to Birmingham University. He was the grandson of Mr. Archibald Kenrick, the founder of the firm with which he was connected for nearly seventy years.

## Contracts Open

**Buenos Aires,** June 12.—Rotary pumps, air compressors, electric welding outfits, etc., for the Argentine State Railways Administration. (D.O.T. reference: T.Y. 22,711/39.)

**Chapel-en-le-Frith,** June 10.—Providing and laying of about 4,300 yds. of 3-in. and 4-in. dia. iron pipes, etc., for the Rural District Council. Brady & Partington, engineers, Market Street, Chapel-en-le-Frith. (Fee £5, returnable.)

**Cork,** June 7.—Iron, steel, non-ferrous metals, castings, for six months, for the Harbour Commissioners. The Engineer's Department, Harbour Office, Cork.

**Forest Hall,** June 12.—Cast-iron goods, lead, copper and iron pipes, tools, etc., during the year ending March 31, 1940, for the Longbenton Urban District Council. Mr. H. G. McNaught, surveyor, Council Offices, Forest Hall.

**Lincoln,** June 5.—New boiler plant, for the Lincolnshire Joint Board for the Mentally Defective. E. G. Phillips, Son & Norfolk, consulting engineers, Arskus House, Annesley Grove, Nottingham.

**Oldham,** June 8.—Supply and erection of electrically-operated sewage pump, for the Town Council. Mr. G. E. Hardy, borough engineer, Municipal Buildings, 75, Union Street, Oldham.

**Rio de Janeiro,** June 5.—234 wagons, for the Central Railways of Brazil. (D.O.T. reference: T.Y. 20,972/39.)

**Southampton.**—Supply and erection of electrically-driven centrifugal pumps, etc., for the Town Council. Mr. J. Hawksley, waterworks engineer, Civic Centre, Southampton. (Fee £5, returnable.)

**Swansea,** June 3.—Wrought-iron railings, gates, etc., for the Town Council. Mr. J. R. Heath, borough engineer, Guildhall, Swansea.

## Company Meeting

### Ransomes & Rapier, Limited

Presiding at the annual meeting of Ransomes & Rapier, Limited, held at Waterside Ironworks, Ipswich, MR. R. R. STOKES, M.P. (chairman and managing director), said that but for the September crisis the value of orders booked during the year would have been normal, a particularly bright feature being that export orders rose steadily during the first half of the year. Both inquiries and orders had very considerably increased since January 1 for home and export, the latter increase no doubt being due to special visits abroad made by members of the staff. The first four months of 1939 had, in fact, shown an increase of 60 per cent. in the value of orders booked over the same period of last year, and, provided that rate continued, the works would continue working at full capacity for the rest of the year. The works were not engaged on any direct armament work, and the only purchases made by any Government Department during the past year had been for their standard products.

## Company Reports

**Leeds Piston Ring & Engineering Company, Limited.**—Net profit to March 31, £11,640; brought in, £7,639; dividend of 10 per cent.; taxation, £6,522; carried forward, £6,757.

**Newton Bros. (Derby), Limited.**—Net profit for year ended March 31, £35,342; brought in, £3,557; to general reserve, £28,200; dividend of 12½ per cent.; carried forward, £7,119. Meeting, June 21.

**John Harper & Company, Limited.**—Profit for the year ended March 28 last, £43,650; balance available after dividends on both classes of preference shares and an interim dividend of 3 per cent. on the ordinary shares, £32,384; final dividend of 10 per cent., making 13 per cent., £14,500; further dividend of 6 per cent. on the employees' preference shares, £462; reserve for premiums payable on redemption of preference capital, £8,000; carried forward, £9,422. Meeting, June 16.

## Forthcoming Event

JUNE 12-17.

*International Foundry Congress and 37th Annual Conference of the Institute of British Foundrymen*;—In London, with headquarters at the Dorchester Hotel, Park Lane, W.1. For full details, see F.T.J., April 13, pp. 303-4.

# X NOW ... passed 200 heats

## ROTALINE ... this strong and durable refractory Lining

## ... gives *longer life* in Rotary furnaces

Here is proof of the remarkable durability of Rotaline . . . this photograph, reproduced by the courtesy of L.M.S. Rly. Co., shows a Sesci furnace at their Crewe Works being tapped. This furnace, which is used for melting steel, is lined with Rotaline, and at the time the photograph was taken the furnace had completed 140 X heats. The lining is still in good condition. Rotaline presents a strong, durable lining resistant to hard usage, while its low volume change obviates cracking and flaking of the lining.

# GENERAL REFRACTORIES Ltd.

*Telephone:* *Sheffield* 31113 (6 *lines*). **GENEFAX HOUSE, SHEFFIELD, 10** *Telegrams:* "*Genefax, Sheffield.*"

# Raw Material Markets

Owing to the very active conditions which now prevail in most sections of the iron and steel industry, many producing works were employed during the Whitsun holiday. The foundry pig-iron trade is still not benefiting from the increased number of orders now circulating in the industry, and makers are able to meet consumers' requirements from the current low outputs.

## Pig-Iron

**MIDDLESBROUGH.**—Only small tonnages of Cleveland foundry iron are changing hands each week, and, in view of the holiday on Monday, there has been even less activity than usual. Despite the pronounced lack of orders, it is not expected that quotations will be lowered, but while doubt exists on this point, buyers will continue to buy on a hand-to-mouth policy. For delivery in the Middlesbrough or Falkirk areas, No. 3 Cleveland G.M.B. foundry iron is quoted 99s., No. 1 foundry iron 102s., No. 4 foundry and No. 4 forge 98s., all less 5s. per ton rebate. Deliveries on Clydeside are charged at 3s. above the foregoing figures.

Holiday interruptions have contributed to make the past few days very quiet in the hematite section of the market; in fact, business has not been at all brisk since the announcement was made that prices would be reduced by 5s. per ton as from July 1. Consumption is quite satisfactory, but consumers will use up as much of their stock as possible before they re-enter the market. It is expected that there will be a strong buying movement after the end of the first half of the year. Prices for home business are based on East Coast mixed numbers at 120s., delivered on the North-East Coast, 125s. 6d. in Sheffield, and 131s. in the Midlands. There is not very much export trade being done at the present time, despite the fact that lower prices are quoted to foreign buyers.

**LANCASHIRE.**—Consumers of foundry pig-iron have not displayed much interest in new business during the past week, and the market continues to rule quiet. The holidays, of course, must be held partly responsible for this, but, nevertheless, there is a marked reluctance to extend existing commitments. Most consumers have already ensured that they receive adequate supplies over the next few months, and while there is a chance of lower prices ruling later, they will not consider new contracts. Although no official pronouncement on the question of future quotations has been made, it is not anticipated in well-informed circles that there will be any reductions. It is pleasing to report that there has been a slight improvement in activity among several jobbing founders, while the call for deliveries under contract from other consumers has been fairly good. With regard to hematite, there has been some inclination to book new orders, but in most instances current contract deliveries suffice to meet requirements. Large-scale buying will not be entered into until the reduced prices operate after the end of June.

**MIDLANDS.**—Consumption of high-phosphorus iron is still very restricted, owing largely to the light-castings foundries being on short time through lack of work. Most users have covered their needs over the next few months, and are only drawing slowly on their booked tonnages. Low-phosphorus iron, on the other hand, continues to move away freely and trade in this section is active. Heavy engineers and machine-tool makers, etc., are well employed, and consumption of low-phosphorus iron is likely to be heavy for a considerable time to come. Current quotations range from about £5 10s. to £6, delivered Midland stations. Hematite is also well taken up, and consumers are accepting deliveries at a good rate.

**SCOTLAND.**—Only moderate tonnages of pig-iron are being ordered, and consumers generally will not buy forward. There has been no improvement in the light-castings trade, which continues to be badly situated for work. No. 1 foundry iron is quoted at 108s. and No. 3 at 105s. 6d., f.o.t. furnaces. Business in steel-making irons is quite good and local works are still very busy. A shipment of Indian basic iron of over 7,000 tons recently arrived at Glasgow. Hematite mixed numbers are quoted at 20s. 6d. and basic iron at 92s. 6d., both delivered and less 5s. rebate.

## Coke

Although the tone of the foundry-coke market continues to be firm, not very much new buying is being done at present, as some consumers are hopeful of lower prices ruling during the third quarter of the year. Producers have not yet made any announcement with regard to future quotations, but it is generally expected that the minimum price for both Durham and Welsh coke after the end of June will be maintained at the existing level of 50s. 6d., delivered Birmingham and Black Country stations.

## Steel

Most steelworks were fully employed over the Whitsun holiday, and the pressure for supplies of all descriptions of steel is maintained. Structural engineers engaged on Government work are taking up heavy tonnages of finished material, and while deliveries are being made very satisfactorily on the whole, the works have received heavy tonnages for current rolling. Shipbuilders have recently placed increased orders for plates, and this section is becoming very brisk. Joists, sections and plates are being well bought up on forward account, and many consumers have covered their requirements up to the end of the year. Prices have been fixed until the end of October, and business after that has been negotiated subject to a rise-and-fall clause.

## Scrap

Owing to the shortage of scrap, steelworks are making increased use of basic iron for charging their furnaces. This, of course, is unsatisfactory to them, as it substantially raises their costs of production, but the present position leaves them with no alternative. Little relief can be expected until scrap recently purchased in the United States arrives in this country. Some has already been unloaded here, but not sufficient to make any real impression on the market.

## Metals

**Copper.**—Although there has not been much new buying during this week, the tone of the market has been quite firm. Prices in this country rallied on reports that the Anaconda Copper Company had suspended operations at its Stewart mine, in Montana. It is understood that unless there is a pronounced improvement in the domestic copper demand in the United States, other concerns may follow the lead of Anaconda and reduce production. Based on the April rate of absorption, United States copper stocks are equivalent to about eight months' requirements.

Metal Exchange quotations were as follow :—

*Cash.*—Thursday, £41 16s. 3d. to £41 17s. 6d.; Friday, £42 2s. 6d. to £42 3s. 9d.; Tuesday, £42 5s. to £42 6s. 3d.; Wednesday, £42 15s. to £42 16s. 3d.

*Three Months.*—Thursday, £42 2s. 6d. to £42 3s. 9d.; Friday, £42 10s. to £42 11s. 3d.; Tuesday, £42 12s. 6d. to £42 13s. 9d.; Wednesday, £43 2s. 6d. to £43 3s. 9d.

**Tin.**—New business in this market also has been rather quiet, but quotations have been well maintained; in fact, the price of cash tin reached the highest closing level since October, 1937, last week. Speaking at the general meeting of the F.M.S. Chamber of Mines at Ipoh, on May 24, Colonel Hornidge, the President, alluded to the tin restriction scheme, and said that the number of unemployed had reached serious proportions. The preposterously high price of quota rights had tended to enhance the unhealthy artificial state of the industry.

The May issue of the Statistical Bulletin of the International Tin Research and Development Council (Statistical Office, 21, Prinsessegracht, The Hague, price 1s.) states that world tin production in March is estimated at 7,500 tons, the lowest figure for more than five years. The total for the first quarter is 33,400 tons, a decrease of 23 per cent. as compared with the first quarter of 1938. World apparent tin consumption in March is estimated at 13,400 tons, making the total for the first quarter 35,700 tons, a decrease of 13 per cent. as compared with the first quarter of last year. Consumption in the United Kingdom shows an increase of 800 tons to 5,200 tons. World tinplate production in the first quarter amounted to 950,000 tons, an increase of 24 per cent. as compared with the first quarter of last year.

Official quotations were as follow :—

*Cash.*—Thursday, £225 15s. to £226; Friday, £226 10s. to £226 15s.; Tuesday, £226 10s. to £226 15s.; Wednesday, £227 5s. to £227 10s.

*Three Months.*—Thursday, £223 15s. to £224; Friday, £224 5s. to £224 10s.; Tuesday, £224 7s. 6d. to £224 10s.; Wednesday, £225 to £225 5s.

**Spelter.**—It was announced last week that, on the recommendations of the Import Duties Advisory Committee, the Treasury had increased the Customs duty on unwrought zinc to 30s. per ton as from May 26. The previous duty was 12s. 6d. per ton, or 10 per cent. *ad valorem*, whichever is the less. Following this announcement, spelter prices rose to the highest levels of the year. The import duty decision has rather cleared the air in the zinc industry, and it is expected that there will shortly be moves to re-form the International Zinc Cartel.

Daily market prices :—

*Ordinary.*—Thursday, £13 18s. 9d.; Friday, £14 1s. 3d.; Tuesday, £14 2s. 6d.; Wednesday, £14 3s. 9d.

**Lead.**—Only a moderate demand for lead has been made, but it is noticeable that selling pressure has been relaxed. The opinion that there was a more optimistic note in the building industry and that conditions were beginning to improve was expressed by Mr. Kenneth Bellman at the International Building Club, of which he is chairman. Given peace, he said, there would probably be a good deal of house building in the next five or six months, and the work should then stabilise itself at a higher level than at present.

Day-to-day quotations :—

*Soft Foreign (Prompt).*—Thursday, £14 7s. 6d.; Friday, £14 1s. 3d.; Tuesday, £14 12s. 6d.; Wednesday, £14 13s. 9d.

**Scrap.**—There has been little business about during this week, and the holiday has accentuated the quietness of the market. Approximate selling prices for old metal :—New aluminium cuttings, £69; rolled, £57; cast, £30 to £35; foil, £80. Copper £38 to £43; braziery, £35 to £36. Brass (clean), £22 to £25. Zinc, £10s. Lead, £13 10s. Gunmetal, £38.

## New Companies

*(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)*

**Hedley S. Hunt & Company, Limited,** 2, South Place, Moorgate, London, E.C.2.—Capital, £1,600. Iron, brass and bronze founders, etc. Directors: E. Hunt and H. C. Newton.

**Sir Robert McAlpine & Sons (Birmingham), Limited.**—Capital, £100,000. Public works and general engineering contractors, etc. Directors: Sir Malcolm McAlpine, Sir Alfred McAlpine, R. E., W. H., T. G. B., M. D., M. H. D. and R. McAlpine, and D. P. Malcolm, 50, Pall Mall, London, S.W.

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